



This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

- + *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.
- + *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.
- + *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.
- + *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at <http://books.google.com/>

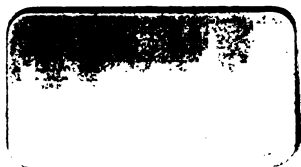


Edw T 20208.72.465

**Harvard College
Library**



By Exchange

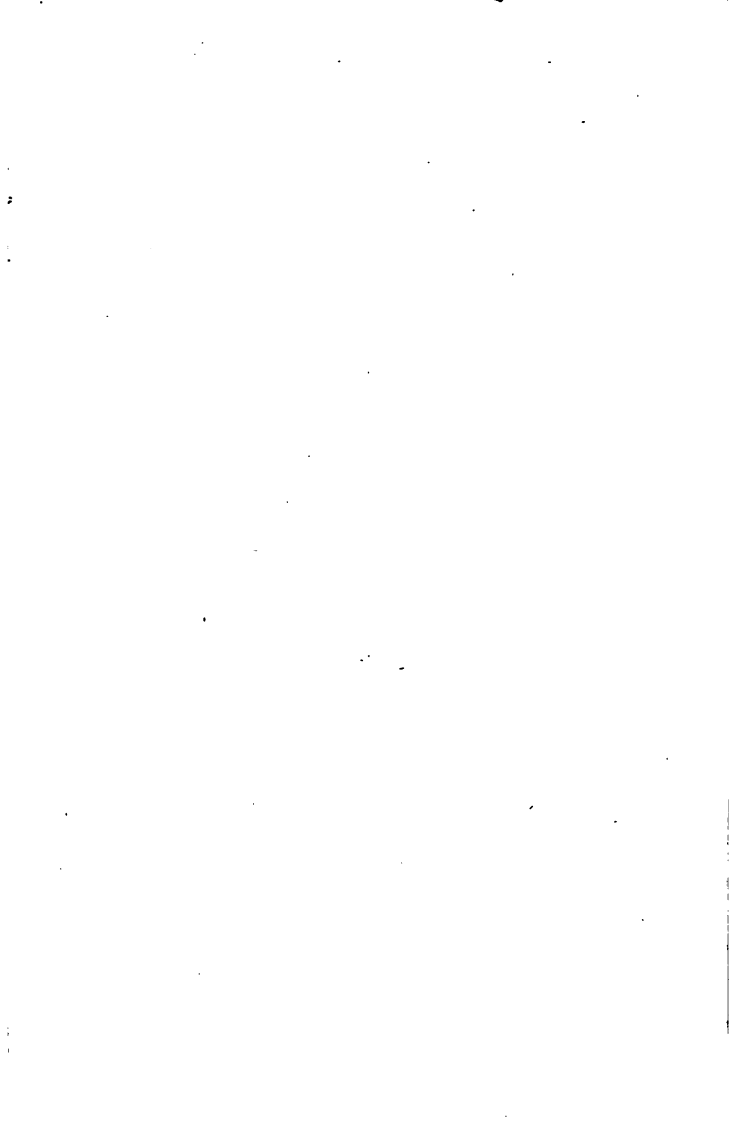




3 2044 102 874 302

D. W. Coyt.





8/1.23

PRACTICAL CHEMISTRY.



0
THE OWENS COLLEGE JUNIOR COURSE

Cond
OF

PRACTICAL CHEMISTRY.

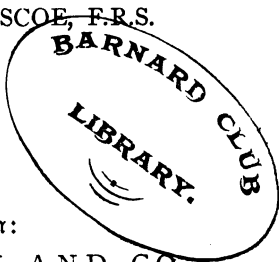
BY

FRANCIS JONES,

Chemical Master in the Grammar School, Manchester.

WITH A PREFACE BY

PROFESSOR ROSCOE, F.R.S.



London:

MACMILLAN AND CO.

1872.

[*The Right of Translation and Reproduction is reserved.*]

✓
Follet 2.0.2.2.72.465-

HARVARD COLLEGE LIBRARY
BY EXCHANGE

FEB 12 1932

LONDON:
R. CLAY, SONS, AND TAYLOR, PRINTERS,
BREAD STREET HILL

B6011.14

P R E F A C E.

THIS little book contains a short description of a course of practical chemistry, which an experience of many years has proved suitable for those commencing the study of the science. The work is, however, not intended to supplant, but rather to supplement instruction given by the Teacher, as it points out the principles of the various processes and names the various reactions without entering into the details of the necessary manipulation, which after all can only be satisfactorily learnt by practical demonstration. The subject-matter has been carefully compiled, under my supervision, by Mr. Francis Jones, formerly Junior Demonstrator in this Laboratory, and many improvements in the analytical tables are due to Mr. Schorlemmer, F.R.S., the Senior Demonstrator.

To those about to use the book, I would give the following advice :—

1. Be sure you understand the theoretical explanation (for which you may have to refer to other books) as well as the practical part of the experiment, or the reaction, which you perform.

2. Keep careful notes of each day's laboratory work, and write out answers to the questions found at the end of these pages.

3. One of the first virtues in the practical chemist is cleanliness. Learn to work neatly, and you will soon obtain exact views of the science. Those who work in a mess not unfrequently get their minds in a muddle.

H. E. ROSCOE.

THE OWENS COLLEGE,

MANCHESTER,

October, 1872.

CONTENTS.

PART I.

	PAGE
Preparation of Apparatus, Gases, &c.	I

PART II.

Blow-pipe Analysis	41
Bunsen's Flame Reactions	46
Preliminary Examination	55

PART III.

Grouping of the Metals	60
Reactions of the Metals of the Silver Group	63
Separation " " " "	65
Reactions " " Copper Group	66
Separation " " " "	70
Reactions " " Arsenic Group	72
Separation " " " "	80
Reactions " " Iron Group	81
Separation " " " "	88
Reactions " " Barium Group	90
Separation " " " "	92
Reactions " " Potassium Group . . .	94
Separation " " " "	96

PART IV.

	PAGE
Grouping and Reactions of the Inorganic Acids . . .	97
Separation of Inorganic Acids.	115
Grouping and Reactions of the Organic Acids . . .	118
Tests for Organic Alkaloids	124
Separation of Organic Acids	131

PART V.

Grouping and Reactions of the Rare Metals	132
---	-----

APPENDIX.

Table of the Elements	147
Questions and Exercises	151
INDEX	169

JUNIOR COURSE OF LABORATORY PRACTICE.

PART I.

PREPARATION OF APPARATUS, GASES, &c.

1. Glass stirring-rods.

Divide a piece of glass rod into several pieces about two decimetres in length. This is done by filing the glass rod at each place where it is to be cut off, with a three-cornered file, and then snapping it across. Knock off any projecting pieces of glass which may be left at the newly-cut edges, and then hold each end of the rod in the flame of a Bunsen lamp until the sharp edges are fused and rounded. The glass rods thus made serve for stirring liquids, &c.

2. A wash bottle.

Soften a cork by gently rolling it under the foot, and fit it air-tight into the neck of a flask about one litre capacity. Then, by means of a round file, bore two holes in the cork about three millimetres in diameter,

and running parallel to each other and to the longer axis of the cork. Next obtain two pieces of glass tubing of the same diameter, one three decimetres long and the other half that length. Hold one end



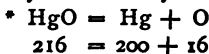
FIG. 1.

of the longer tube in the Bunsen flame until the opening contracts considerably (but take care not to seal it up entirely), and then bend it about half a decimeter from the end, as shown in the figure. This is done by holding the glass tube horizontally in a common batwing gas jet flame, turning it round so as to heat all parts equally, and bending to the proper angle as soon as it feels sufficiently soft. Now round the edge of the wide end of the tube by holding it in the flame till it softens, and when cold fit it into the cork. In a similar way round both ends of the shorter piece of tubing, bend to the angle shown in the figure, and fit into the other hole. Clean out the flask and tubes thoroughly, rinse with distilled water, and then fill up with distilled water.

3. *Preparation of oxygen from mercuric oxide.*

When mercuric oxide is heated it is decomposed into mercury and oxygen.

Mercuric oxide yields mercury and oxygen.



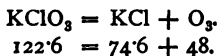
* For the explanation of these symbols a larger work must be consulted. See p. 15 of Roscoe's "Elementary Chemistry."

Place a small quantity of mercuric oxide in a dry test tube, and heat it over a Bunsen lamp. The substance darkens in colour, and a ring of minute globules of mercury soon forms on the cool part of the tube. That the tube contains oxygen may be shown by plunging a glowing chip of wood into it, and observing that the wood will be rekindled. It is advisable to keep the thumb loosely on the mouth of the test tube to prevent the escape of oxygen by diffusion.

4. Preparation of oxygen from potassium chlorate.

Potassium chlorate when heated is decomposed into oxygen and potassium chloride. (See Roscoe, p. 16.)

Potassium chlorate yields potassium chloride and oxygen :

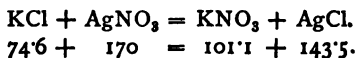


Place a few crystals of potassium chlorate in a dry test tube, and heat gently. The salt soon fuses and then begins to effervesce, giving off oxygen, which may be recognized, as before, by its power of rekindling a glowing chip. When oxygen ceases to be evolved, the residue is a white salt called potassium chloride.

5. Tests for potassium chlorate and chloride.

A solution of potassium chlorate is *not precipitated* by a solution of silver nitrate ; but potassium chloride is *precipitated*, silver chloride being formed.

Potassium chloride and silver nitrate yield potassium nitrate and silver chloride :



Dissolve a crystal of potassium chlorate in distilled water, then add solution of silver nitrate, no precipitate will be formed. Dissolve also the residue of potassium chloride (obtained in 4) in distilled water, and add silver nitrate solution. A curdy white precipitate of silver chloride will at once be formed.

6. Preparation of oxygen from potassium chlorate and manganese dioxide.

Potassium chlorate when mixed with about one-fifth of its weight of manganese dioxide, gives off its oxygen at a much lower temperature than when heated alone, although the oxide itself remains quite unaltered.

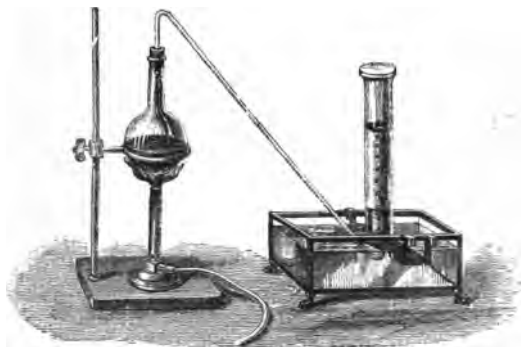


FIG. 2.

Place in a small flask (about 100 cubic centimetres capacity) a mixture of potassium chlorate and manganese dioxide in the proportions already mentioned. Then fit into the neck of the flask a cork through

which a bent conducting tube passes, the lower end of which is placed under water in the pneumatic trough. Fill some gas jars with water and invert them in the trough. Support the flask on a retort stand, and heat the mixture (Fig. 2); as soon as heat is applied, bubbles of gas will begin to rise through the water, consisting of air expelled from the flask by the heat. These are allowed to escape, and the oxygen, which soon begins to come off abundantly, is collected by placing the inverted bottles over the end of the conducting tube, and thus allowing the bubbles of oxygen to ascend into the bottles and displace the water. As soon as the first bottle is filled with oxygen, place a shallow earthenware tray under the neck, and remove it from the trough, taking care that the tray contains enough water to prevent the escape of the gas. When four bottles have been filled in this manner, remove the flask and conducting tube and allow the former to cool.

7. The residue from the preparation of oxygen from potassium chlorate and manganese dioxide is potassium chloride, and unaltered manganese dioxide.

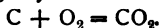
Dissolve in water the residue in the flask from the preparation of oxygen, filter from the insoluble manganese dioxide, and evaporate the filtrate in a porcelain basin to a small bulk; on cooling, crystals of potassium chloride will separate out. Pour off the mother liquor, dry the crystals between filter paper, and keep them in a small bottle for future experiments.

8. Combustions in oxygen.

When a taper is burned in oxygen, the carbon which

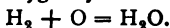
it contains unites with the oxygen, forming carbon dioxide (carbonic acid gas), and the hydrogen also unites with the oxygen, forming hydrogen monoxide (water).

Carbon and oxygen yield carbon dioxide :



$$12 + 32 = 44.$$

Hydrogen and oxygen yield water :



$$2 + 16 = 18.$$

Place a small piece of taper on an iron wire support, light it, and plunge it into one of the jars of oxygen (prepared in 6). Observe that it burns much more brightly than in air. Withdraw it, blow the light out, and if only a spark remain on the wick, observe that when again plunged into the oxygen it is at once rekindled. This serves as a convenient test for the presence of oxygen. When solution of calcium hydrate (lime water) is placed in contact with carbon dioxide, calcium carbonate (chalk) and water are formed, and the former, being insoluble in water, is precipitated as a white powder.

Calcium hydrate and carbon dioxide yield calcium carbonate and water :



$$74 + 44 = 100 + 18.$$

Prove that the jar in which you have burned the taper contains carbon dioxide, by adding a little clear lime water to it and shaking so as to bring the gas and liquid in contact. A white precipitate will be formed, consisting of calcium carbonate.

9. *When charcoal is burned in oxygen carbon dioxide is produced.* (Compare 8.)

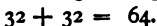
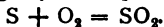
Place a few pieces of charcoal, about the size of peas, in the deflagrating spoon, hold this in the lamp-flame till the charcoal is just kindled, and then plunge the spoon into a jar of oxygen. The charcoal will burn with great brilliancy, and, if enough oxygen be present, nothing will remain on the spoon but a little white ash (the inorganic matter in the charcoal).

Prove the presence of carbon dioxide (as in 8) by adding lime water.

A similar union of carbon and oxygen takes place in animals when breathing, but the combustion is slow, not rapid. A portion of the carbon of their bodies unites with the oxygen which they inhale from the air, and carbon dioxide is produced. Observe this by blowing the air from the lungs through a glass tube into some clear lime water, a white precipitate of calcium carbonate soon forms, caused by the union of the carbon dioxide of the breath with the lime. (See Roscoe, p. 14.)

10. *When sulphur is burned in oxygen, sulphur dioxide (sulphurous anhydride) is produced.*

Sulphur and oxygen yield sulphur dioxide :



Place a few pieces of sulphur in the deflagrating spoon, heat until the sulphur is melted and takes fire, and then plunge it into a jar of oxygen. Observe that the sulphur, which only burned feebly in air, burns

with considerable brightness in oxygen. When it has ceased to burn, remove the spoon, and observe the suffocating odour of the gas which has been produced.

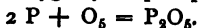
Free acids redden blue vegetable colouring matters.

Show that sulphur dioxide when dissolved in water forms an acid, and on pouring a solution of blue litmus into the wet bottle in which the sulphur was burned, observe that the blue colour is changed to red.

11. When phosphorus is burned in oxygen, phosphorus pentoxide (or phosphoric anhydride) is produced.

This is not a gaseous body like the dioxides of sulphur and carbon, but is a white solid substance, which very readily unites with water, forming tri-hydrogen phosphate (tribasic phosphoric acid).

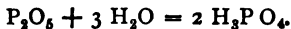
Phosphorus and oxygen yield phosphorus pentoxide :



$$62 + 80 = 142.$$

When the oxygen has been collected over water, there is always enough moisture in the gas-jar to unite with the pentoxide, and form a solution of phosphoric acid ($\text{H}_3 \text{ P O}_4$), thus :

Phosphorus pentoxide and water yield tri-hydrogen phosphate :



$$142 + 54 = 196.$$

Place a small piece of phosphorus (having carefully dried it with filter-paper) on the deflagrating spoon, light it by touching it with a hot wire, and place it in a jar of oxygen. Observe the intensely brilliant light with which it burns, and the dense white

fumes of phosphorus pentoxide which are produced. Observe too that in a short time these fumes disappear for the reason already mentioned; and show that an acid is present by pouring in some litmus solution and observing the change of colour from blue to red.

12. Presence of oxygen in air.

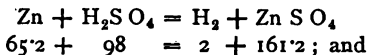
Oxygen is present in the air diluted with another gas called nitrogen. In one hundred volumes of air, about twenty-one consist of oxygen, and seventy-nine of nitrogen. When substances burn in air they unite with the oxygen in it and produce oxides, just as they do when burned in the pure gas.

Burn a taper, sulphur, and phosphorus in three jars of air, and prove that carbon dioxide, sulphur dioxide, and phosphorus pentoxide are respectively produced. Ascertain this by applying the same tests as in 8, 10, and 11.

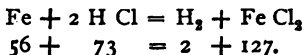
13. Preparation of hydrogen.

Certain metals, such as zinc, magnesium, and iron, yield hydrogen gas when they are acted on by acids, a salt of the metal with the particular acid employed, being formed at the same time, thus:

Zinc and sulphuric acid yield hydrogen and zinc sulphate:



iron and hydrochloric acid yield hydrogen and ferrous chloride



Place a few pieces of zinc in a wide-mouthed flask provided with a cork, through which pass two tubes, one a bent conducting tube for leading the gas into the pneumatic trough, the other a funnel tube for supplying acid to the zinc. Fill four jars with water, and collect the gas (which is given off without the aid of heat) in the same way as in the case of oxygen (Fig. 3). Having placed the end of the conducting tube in

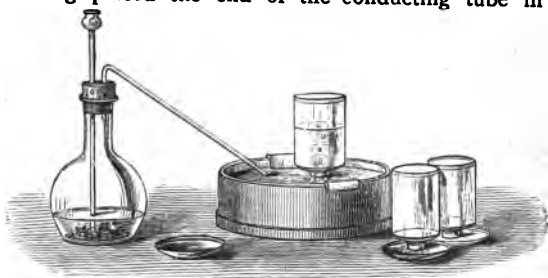


FIG. 3.

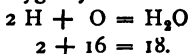
the pneumatic trough, pour down the funnel tube enough water to cover the zinc completely, and then add sulphuric acid by degrees and cautiously, shaking the flask so as to mix the acid and water. The gas will soon come off with increasing rapidity, but the first portion *must be rejected, as air and hydrogen form an explosive mixture*. It is therefore necessary to wait until all the air has been expelled from the flask by the hydrogen. Before filling the jars, collect a test-tube full of the gas over the pneumatic trough, and apply a light to it (holding the mouth downwards); if

it burn quietly, you may safely proceed to fill the gas jars, but if a slight explosion occur, you must wait until another test-tube is collected and found to burn quietly. As soon as this is the case, fill four jars with the gas, and remove them from the trough in the same way as described in 6.

14. *Production of water by the burning of hydrogen in air.*

Whenever hydrogen burns in air or in oxygen, water is produced.

Hydrogen and oxygen yield water :



Remove the conducting tube from the hydrogen flask above described (but without removing the cork), and substitute for it a straight piece of glass tube of the same diameter, drawn out at the upper end so as to form a jet (Fig. 4). As all the air has long ago been expelled, the hydrogen issuing from the jet may be safely lighted. Hold over this flame a perfectly dry beaker, or test-glass, and observe the instant deposit of moisture on the sides of the glass. This is caused by the union of the hydrogen with the oxygen of the air contained inside the beaker.



FIG. 4.

15. *The residue from the preparation of hydrogen from zinc and sulphuric acid is zinc sulphate.*

Filter a portion of the contents of the flask used for preparing hydrogen from the undissolved zinc, and evaporate the filtrate to a small bulk. On cooling, crystals of zinc sulphate will be formed, which are drained from the mother liquor, dried between filter paper, and kept in a corked tube or bottle for future examination.

16. *Hydrogen is an inflammable gas.*

Apply a light to one of the jars of hydrogen, and observe that it burns. Notice also the deposit of moisture on the sides of the gas jar caused by the union of the hydrogen with the atmospheric oxygen.

17. *Hydrogen is lighter than air.*

Show this by pouring the contents of one jar, *upwards*, into a jar of air held above the mouth of the hydrogen jar. The hydrogen in virtue of its lightness will leave the lower jar and displace the air from the upper jar. Apply a light to each jar, and observe that the one originally filled with hydrogen no longer contains any, while the other originally filled with air contains hydrogen.

18. *Hydrogen does not support combustion.*

Take another jar of hydrogen, held mouth downwards, and push up into it a lighted taper, supported on a straight wire. The hydrogen will burn at the mouth of the jar, but the taper will be extinguished. The taper may be withdrawn, relighted, and re-extinguished two or three times.

19. *Preparation of nitrogen.*

When phosphorus is burned in air, it unites with the

oxygen, forming phosphorus pentoxide (P_2O_5), which dissolves in water, whilst the residue is nitrogen.

Place a small piece of dry phosphorus on a porcelain crucible lid, and fix this on a flat piece of cork, so that the lid may be floated on the water in the pneumatic trough, or other tray containing water. Light the phosphorus, and quickly surround it with a bell-jar, the tubulure of which is closed with a cork (Fig. 5). A



FIG. 5.

portion of the air will first be expelled by the heat, and the phosphorus will continue to burn as long as any oxygen remains in the air of the bell-jar; when that is exhausted it will cease to burn. Observe that the water rises inside the bell-jar, replacing the oxygen, which is no longer gaseous, but has combined with the phosphorus to form phosphorus pentoxide. Wait a few minutes to allow the pentoxide to be completely dissolved by the water. The bell-jar then contains nitrogen.

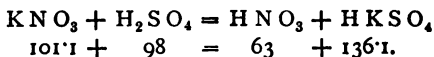
20 *Nitrogen does not support combustion, and is not combustible.*

Place a lighted taper in the bell-jar, and observe

that the flame is at once extinguished, and that the gas does not burn.

21. Preparation of nitric acid.

All nitrates when heated with sulphuric acid are decomposed, nitric acid and a sulphate being formed. Thus, when sulphuric acid acts on potassium nitrate (nitre or saltpetre), nitric acid, and hydrogen potassium sulphate (bisulphate of potash) are produced :



Put about twenty grams of potassium nitrate (nitre) in a small stoppered retort, place in the tubulure

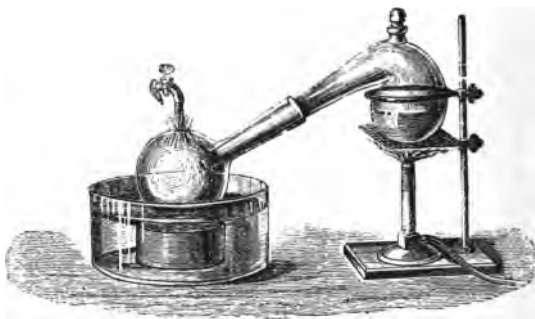


FIG. 6.

a small funnel, and through this pour the same weight of strong sulphuric acid. Withdraw the funnel without soiling the neck of the retort, place the stopper in the tubulure, and support the retort upon a piece of wire

gauze placed across the ring of the retort stand. Let the neck of the retort pass into a clean flask, so arranged that a stream of water may fall on it, and thus aid the condensation of the acid (Fig. 6). Now heat the retort, and observe the formation of red fumes (lower oxides of nitrogen) and soon after, the condensation of the nitric acid on the neck of the retort. When the contents of the retort cease to boil, withdraw the lamp, separate the receiving flask containing the nitric acid from the retort, and pour out the contents of the latter into a *dry* porcelain dish. When cold, break up the cake of hydrogen potassium sulphate thus formed, and preserve it for future examination.

22. Tests for nitric acid.

(a) Add a few drops of the nitric acid prepared as above to a solution of indigo contained in a test-tube. The blue colour will speedily disappear owing to the oxidizing action of the nitric acid.

(b) Place a few bits of copper turnings in a test-tube, cover them with water, and add a little nitric acid. The copper soon begins to dissolve, forming a blue solution, and at the same time brown vapours fill the test-tube. In this case also the nitric acid acts as an oxidizing agent, forming copper nitrate, and red fumes of the oxides of nitrogen are given off. For explanation see 30 and 31.

(c) Add a few drops of nitric acid to a little water contained in a test-tube, and then add some strong sulphuric acid, and shake until the liquids are thoroughly mixed. Allow this mixture to cool *completely*,

and then pour gently on to the surface of the liquid a solution of ferrous sulphate prepared by dissolving a few crystals of the salt in water. This solution is lighter than the other, and if poured on gently will form a layer of liquid resting on the heavier sulphuric acid, and a black ring will form where the two liquids meet. This is caused by the liberation of nitrogen dioxide (by the action of the H_2SO_4 on the HNO_3), which forms a dark-coloured compound with the ferrous sulphate. On shaking the tube, nitrogen dioxide will escape with effervescence, and the black ring will disappear.

Retain a portion of nitric acid for 27.

23. Tests for nitrates.

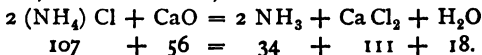
The same reactions may be used to test for combined nitric acid (*i.e.* nitrates), but sulphuric acid must first be added to liberate it.

Repeat the tests *a*, *b*, and *c* (22), substituting for the nitric acid a solution of potassium nitrate in water, to which a few drops of strong sulphuric acid have been added.

24. Preparation of ammonia.

When caustic alkalies act on salts of ammonium, ammonia gas is liberated. Thus :

Ammonium chloride and caustic lime yield ammonia, calcium chloride, and water :



Place about thirty grams of powdered ammonium chloride (sal-ammoniac) and the same weight of pow-

dered lime in a large flask provided with a tightly-fitting cork, through which passes a tube bent as shown in the figure. Place an inverted dry gas-jar over this tube, and heat the mixture in the flask. After the air has been expelled, the ammonia gas will come over, and in virtue of its lightness be retained in the jar. When the jar is filled, remove it from the

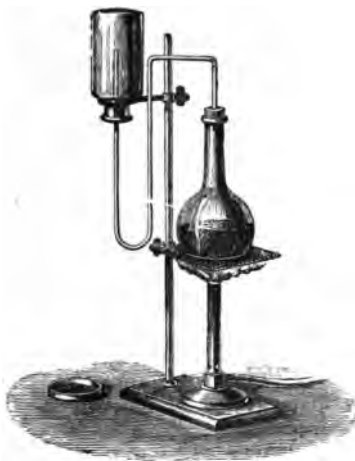


FIG. 7.

upright tube, place the palm of the hand on the mouth, and immerse the jar (mouth downwards) in the pneumatic trough filled with water : the gas will be rapidly absorbed, and the water will rise so as to fill the jar.

Now change the tube for one bent twice at right angles (as in Fig. 10), and allow the remaining gas to pass into some distilled water contained in a beaker. The gas bubbles will be completely absorbed, and when the gas ceases to be evolved, be careful to withdraw the conducting tube from the liquid, so as to prevent it being sucked back into the hot flask.

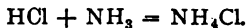
25. Tests for ammonia.

(a) Observe the pungent and very characteristic smell which the solution of ammonia in water possesses.

(b) Place a piece of reddened litmus paper *above* the solution, and observe that the vapour given off is able to change the colour from red to blue. Place the litmus paper *in* the solution, and the change will be still more marked.

(c) Hold a glass rod which has been dipped in fuming hydrochloric acid over the solution of ammonia: it will at once form white fumes of ammonium chloride, caused by the union of the acid and volatile alkali.

Hydrochloric acid and ammonia yield ammonium chloride:



$$36.5 + 17 = 53.5.$$

26. The residue from the preparation of ammonia from ammonium chloride and lime is calcium chloride.

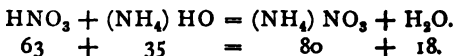
Dissolve a portion of the residue contained in the flask used to prepare ammonia, in water, filter from excess of lime, and evaporate the solution to dryness. A white salt results, which is detached from the evapo-

PREPARATION OF NITROUS OXIDE. 19

rating basin, and preserved in a well-stoppered bottle for future examination.

27. *Preparation of ammonium nitrate.*

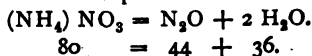
Nitric acid, when neutralized with ammonia, yields ammonium nitrate and water :



Place some nitric acid (21) in an evaporating basin, and dilute with twice its bulk of water ; add ammonia solution (24) cautiously, and with constant stirring until a drop of the liquid ceases to colour litmus paper red. Observe that as the ammonia is added the red colour caused by the nitric acid disappears, and a point is reached when the liquid neither reddens litmus paper nor turns it blue. When this is the case the acid is said to be exactly neutralized, and the addition of ammonia must be stopped. Evaporate the solution of ammonium nitrate thus obtained, until all the water is expelled ; when this is the case, withdraw the lamp and allow to cool ; a cake of fused ammonium nitrate is then obtained. If the salt does not solidify on cooling, heat must be again applied.

28. *Preparation of nitrogen monoxide (nitrous oxide).*

When ammonium nitrate is heated, nitrogen monoxide and water are produced. Thus :



Break the cake of ammonium nitrate (27) into small pieces, and introduce them into a small dry flask

provided with a conducting tube as in 6. Heat gently, and after allowing the air in the flask to be expelled, begin to collect the gas which is produced. As this gas is soluble to a considerable extent in cold water, it is better to fill the pneumatic trough with warm water, in which the gas is much less soluble. Collect four jars of the gas, and then withdraw the conducting tube from the trough. Do not heat it to the point at which all the ammonium nitrate is decomposed, as towards the close of the evolution of gas the decomposition sometimes becomes complex, and other gases are generated so rapidly that an explosion may occur.

29. Properties of nitrous oxide.

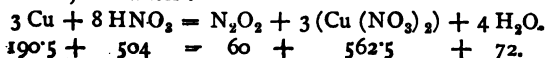
Combustible substances burn in nitrogen monoxide almost as brightly as in oxygen. They decompose the gas, uniting with its oxygen to form oxides, and leaving unaltered nitrogen.

Burn a taper, phosphorus, and sulphur in this gas, in the same manner as they were burned in oxygen. The products of combustion are the same, namely, carbon dioxide, phosphorus pentoxide, and sulphur dioxide; but there is in addition a residue of nitrogen.

30. Preparation of nitrogen dioxide (nitric oxide).

When nitric acid acts upon metals such as copper or mercury, nitrogen dioxide, water, and a nitrate of the metal used are produced. Thus :

Copper and nitric acid yield nitrogen dioxide, copper nitrate, and water :



PREPARATION OF NITRIC OXIDE. 21

Place some copper turnings in a flask provided with a funnel and conducting tube, as in the figure. Cover the copper with a layer of water, and add nitric acid by degrees until the gas comes off steadily. Fill two



FIG. 8.

jars completely, and a third, half full of the gas, and leave the last on the support in the pneumatic trough.

31. *Properties of nitrogen dioxide (nitric oxide).*

(a) Nitrogen dioxide readily unites with free oxygen, forming higher oxides of nitrogen which have a brown colour, $\text{N}_2\text{O}_2 + \text{O} = \text{N}_2\text{O}_3$ and $\text{N}_2\text{O}_2 + \text{O}_2 = \text{N}_2\text{O}_4$. Remove a jar of the gas from the pneumatic trough and expose it to the air. Observe at once the formation of red fumes, consisting chiefly of nitrogen tetroxide (N_2O_4). Now dip the mouth of the jar under water, and observe that these fumes disappear owing to their solubility in water, and at the same time observe the rise of water in the jar.

(b) Allow a few bubbles of oxygen to pass into the bottle half filled with nitrogen dioxide, and observe as

before the formation of red fumes, and the rise of water in the jar as these dissolve.

(c) Nitrogen dioxide does not support the combustion of a taper, but phosphorus, when burning very brightly, is not extinguished when placed in the gas. Place a small piece of dry phosphorus in a spoon, light it, and place it in a jar of nitric oxide: it will be extinguished. Now heat it strongly in the gas flame, and again place it, whilst burning brightly, in the gas, and observe that it continues to burn.

32. Preparation of carbon dioxide (carbonic acid gas).

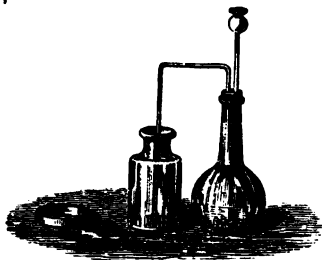
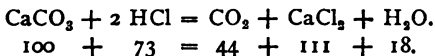


FIG. 9.

When hydrochloric acid acts on calcium carbonate, carbon dioxide, calcium chloride, and water are produced. Thus:



Place some pieces of marble (calcium carbonate) in a flask with funnel and conducting tube, pour some water over it, and then a little hydrochloric acid;

PREPARATION OF CARBON DIOXIDE. 23

a rapid effervescence will begin, and the gas will be given off copiously. It may be collected over water, but as it is much heavier than air it is best collected by downward displacement. This is done by placing the conducting tube at the bottom of the gas-jars, and allowing the heavy gas to collect in them and displace the air (Fig. 9). As the gas extinguishes flame, the jars are ascertained to be full when a lighted taper placed in the mouth is at once extinguished. When this is the case, cover the jar and substitute another ; in this way collect four jars of the gas.

33. *Properties of carbon dioxide.*

(a) Carbon dioxide does not support combustion.

Place a lighted taper in the gas : observe that it is at once extinguished.

(b) Carbon dioxide precipitates lime water.

Add some clear lime water to a jar of the gas : it is at once rendered milky owing to the formation of calcium carbonate (see 8). Cover the jar closely with the palm of the hand and shake the bottle : the hand will adhere to the bottle owing to the partial vacuum caused by the absorption of the CO_2 by the lime-water.

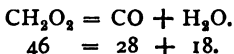
(c) Carbon dioxide is heavier than air.

Pour the carbonic acid from one of the gas-jars into a jar of air. The gas is so heavy that it will displace the air from the jar, and that this is the case may be shown by placing a lighted taper in each jar : the one originally full of air will now be found filled with carbonic acid, whilst the other will, if held mouth downwards for a few minutes, be found to contain only air ;

in the former the taper will be extinguished, in the latter it will continue to burn.

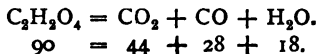
34. Preparation of carbon monoxide (carbonic oxide gas).

This gas is prepared pure by the action of sulphuric acid upon formic acid, which is decomposed into carbon monoxide and water. Thus :



It is, however, frequently prepared by the action of sulphuric acid on oxalic acid ; but in this case a mixture of equal volumes of carbon dioxide and carbon monoxide is obtained.

Oxalic acid yields carbon dioxide, carbon monoxide, and water :



Place some crystallized oxalic acid in a small flask provided with a conducting tube (see Fig. 2), cover it with strong sulphuric acid (oil of vitriol), heat gently on a piece of wire gauze, and after allowing the air to escape, collect the gas in the ordinary way at the pneumatic trough. Fill one gas-jar, and a bottle with a neck narrow enough to allow it to be closed with the thumb. Be careful to remove the conducting tube from the pneumatic trough as soon as the bottles are filled with the gas ; and allow the contents of the flask to become quite cold before pouring the liquid away.

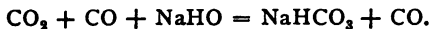
35. Properties of carbon monoxide.

(a) The gas burns with a blue flame even when

PROPERTIES OF CARBON MONOXIDE. 25

mixed with carbon dioxide, as it is when prepared as above. Apply a light to the wide-mouthed gas-jar containing the mixed gases, and observe the pale blue flame with which the monoxide burns.

(b) Pour a small quantity of caustic soda solution into the narrow-necked bottle containing the mixed gases, close it tightly with the thumb, and shake up vigorously without removing the thumb. This will dissolve out the carbonic acid, which is soluble in caustic soda, hydrogen sodium carbonate being formed, and leave the carbonic oxide. Thus :

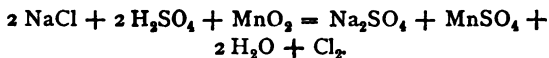


Invert the bottle, mouth downwards, in the pneumatic trough, taking care that the neck is quite covered with water, and withdraw the thumb: water will rush into the bottle and fill the space previously occupied by the carbonic acid. Replace the thumb on the neck of the bottle, and shake again to dissolve the last traces of carbon dioxide, and again place the neck of the bottle under water in the trough, and observe that the space occupied by water is half the total capacity of the bottle. Pour a quantity of the gas thus freed from carbonic acid into a test tube, add a little lime water, and shake it up: no turbidity ought to be produced. Light the gas at the mouth of the test tube, observe the pale blue flame of the carbonic oxide, and after the gas is burned shake up again, and observe that the lime-water is now rendered turbid. This is because the monoxide in

burning takes up oxygen from the air and produces the dioxide (CO_2).

36. Preparation of chlorine.*

When sulphuric acid acts upon a mixture of common salt and manganese dioxide, sodium sulphate, manganese sulphate, water, and chlorine gas are produced. Thus :



$$117 + 196 + 87 = 142 + 151 + 36 + 71.$$

Weigh out 30 grams of common salt and the same quantity of manganese dioxide, and mix them together

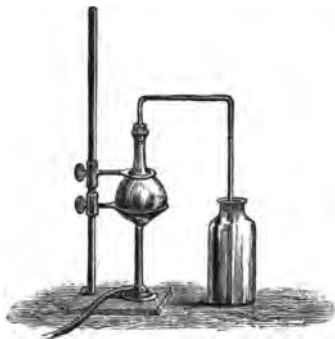


FIG. 20.

in a mortar. Then weigh 60 grams of water, place it in an evaporating basin, and add to it cautiously 60

* Experiments with chlorine must be made in a glass closet provided with a draught, as this gas when inhaled produces great irritation, from which serious results may ensue.

grams of strong sulphuric acid, stirring the liquid with a glass rod until it is thoroughly mixed. The liquid will become very hot, and must be allowed to cool *completely*; it is then poured into a flask (about one litre capacity), the mixture of salt and manganese dioxide is added, and the contents of the flask shaken. The flask is now provided with a conducting tube bent twice at right angles, heat is applied, and the gas collected by displacement like carbon dioxide (Fig. 10). Collect four jars of the gas, and then allow the gas to bubble through some distilled water until no more gas is dissolved. This solution, called *chlorine water*, has a yellow colour, bleaches vegetable colouring matters, and may be conveniently used instead of the gas in many reactions.

37. *Properties of chlorine.*

(a) 1. Chlorine unites readily with hydrogen, forming hydrochloric acid (HCl).

Place a lighted taper in a jar of chlorine, and observe that it now burns with a smoky flame; this is caused by the union of the chlorine with the hydrogen of the taper, while the carbon also present in the taper, is liberated, and causes the abundant smoke.

2. Moisten a strip of filter paper with turpentine (composed, like the taper, of carbon and hydrogen), and plunge it into a jar of chlorine: hydrochloric acid is at once formed, and the liberated carbon again appears as soot. The action is so energetic that the paper generally takes fire, owing to the heat evolved during the reaction.

(b) Chlorine unites readily with finely-divided metals, forming metallic chlorides.

Throw some finely-powdered antimony into a jar of chlorine: union will at once take place with evolution of light, and chloride of antimony will be formed.

(c) Phosphorus and chlorine unite together, forming phosphorus chloride.

Place a piece of dry phosphorus in a deflagrating spoon, and place it in a jar of chlorine. It will take fire spontaneously and continue to burn with a pale non-luminous flame, and chloride of phosphorus will be formed.

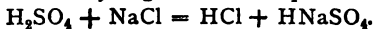
(d) Moist chlorine bleaches vegetable colouring matters by uniting with the hydrogen of the water; the oxygen thus liberated attacks the colouring matter and destroys it.

Place a piece of red cloth, partly moistened and partly dry, in a jar of chlorine. The dry part will remain unaltered, but the moist portion will be rapidly bleached.

38. *Preparation of hydrochloric acid.*

When sulphuric acid and sodium chloride react on each other, hydrogen-sodium sulphate (bisulphate of soda) and hydrochloric acid are formed.

Sulphuric acid and sodium chloride yield hydrochloric acid and hydrogen-sodium sulphate:



Place in a flask (about a litre in capacity), provided with a funnel and conducting tube, about 30 grams of common salt. Fit the end of the conducting tube

into a small bottle containing a little water, which serves to wash the gas, and the tube which passes out of this bottle conducts the purified gas into 100 c. c.* distilled water, as in the figure. When the apparatus is arranged, add by degrees about 50 grams of strong sulphuric acid. The gas will come off at first with-

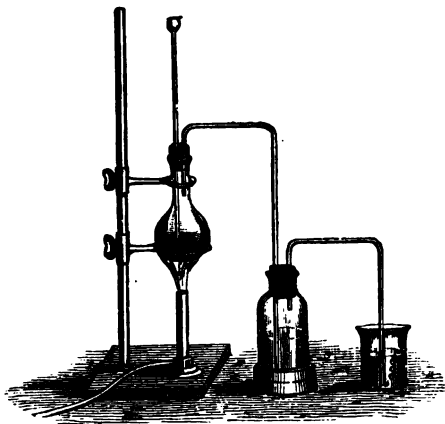


FIG. 11.

out heating ; when all the acid has been added and the evolution of gas slackens, heat the flask gently on a piece of wire-gauze or on a sand bath. Observe that the water in the wash-bottle has first to be saturated, and that then the gas begins to be absorbed by the distilled water. When this last fumes strongly, remove

* c. c. = contraction for cubic centimetres

the wash-bottle and fill a cylinder with the gas by downward displacement. (See Fig. 10.)

39. Properties of hydrochloric acid.

(a) Hydrochloric acid is extremely soluble in water.

Close the cylinder filled with hydrochloric acid gas with a glass plate, invert it, mouth downwards, in a vessel of water coloured with blue litmus, and withdraw the glass plate. Observe the rapid rise of the water inside the cylinder caused by the solution of the gas, and the change of colour from blue to red, showing the acid nature of the solution.

(b) Hydrochloric acid is a powerful acid.

Take some of the aqueous solution of the gas (prepared in 38) and add a drop or two of litmus solution to it, so as to colour the solution red. Now add a solution of caustic soda, constantly stirring the mixture, and observe that a point is reached when the red colour is changed to a faint blue colour. This point denotes that all the acid has been saturated. Evaporate the solution and obtain crystals of sodium chloride (common salt).

These three substances, viz. the hydrochloric acid, the caustic soda, and the sodium chloride, are examples of three quite distinct classes of chemical compounds, called respectively, acids, bases, and salts. (For a description of these three kinds of substances see Roscoe's "Chemistry," p. 66).

(c) Ammonia and hydrochloric acid unite to form ammonium chloride.

Hold a glass rod dipped in ammonia solution over

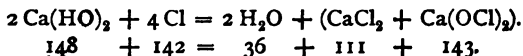
BLEACHING ACTION OF CHLORINE. 31

the HCl solution, and observe the white fumes of NH_4Cl produced. (See also 25.)

40. Preparation of calcium hypochlorite (or bleaching powder).

Chlorine gas is rapidly absorbed by slaked lime, and calcium hypochlorite is formed.

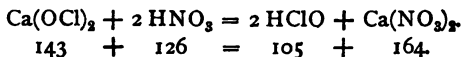
Lime and chlorine yield water and bleaching powder (chloride and hypochlorite of calcium):



Place a small quantity of slaked lime in a beaker, fill up with water so as to have a milky liquid containing lime in suspension, and then allow chlorine to bubble through until the solution smells strongly of it: calcium hypochlorite will be found in solution. Place a piece of red cloth in some of this solution, and subsequently in a little dilute HCl: chlorine will be liberated by the action of the acid, and the cloth will be bleached.

41. Preparation of hypochlorous acid.

When diluted nitric acid is added to calcium hypochlorite, hypochlorous acid and calcium nitrate are formed. Thus:

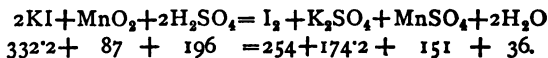


Place a solution of the bleaching liquor, as prepared above, in a stoppered retort, the neck of which passes into a small flask kept cool by a stream of water. Add a few drops of *dilute* nitric acid to the contents of the retort, and boil the liquid: the distillate

contains a colourless solution of hypochlorous acid, which will rapidly bleach a piece of red cloth placed in it. Observe also the peculiar smell of hypochlorous acid, and remember that a solution of chlorine in water (which likewise bleaches) has a yellow colour.

42. Preparation of iodine.

When sulphuric acid acts upon a mixture of potassium iodide and manganese dioxide ; iodine, potassium sulphate, manganese sulphate, and water are produced. Thus :



Place in a retort (provided with a receiver kept cold by a stream of water) a few grams of potassium iodide and a little manganese dioxide, add *dilute* sulphuric acid, and heat gently. Observe the violet vapours filling the retort as soon as the iodine is given off, and the grey deposit of iodine on the neck of the retort and in the receiver. If a large quantity forms in the retort neck, heat it gently, so as to obtain as much as possible in the receiver.

43. Properties of iodine.

(a) Iodine is very sparingly soluble in water, more so in alcohol, and very soluble in a solution of any alkaline iodide.

Separate the iodine obtained above, from any liquid which has distilled over, and divide it into three small portions and one large portion. Add to one of the small portions some water, to another some alcohol, and to the third a solution of potassium iodide, and

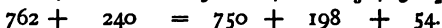
observe the colours varying from pale to dark brown, which the solutions possess.

(b) Free iodine forms with starch a compound called iodide of starch, which has a dark blue colour.

Powder a piece of starch (about the size of a pea) in a mortar, stir it up with about 25 c. c. of cold water, and then heat the mixture (preferably in an evaporating basin) till it boils. A thin, clear solution of starch is thus obtained; add a portion of it to about a quarter of a litre of water, and then a few drops of one of the solutions of iodine, and observe the deep blue colour which the liquid assumes. Heat a little of this blue liquid in a test tube, and observe that the colour disappears; allow it to cool, and observe the reappearance of the colour.

44. *Preparation of sodium iodide.*

Iodine is dissolved by a solution of caustic soda, and sodium iodide (NaI) and iodate (NaIO₃) are produced.



Place the larger portion of iodine prepared as above in an evaporating basin, add water and caustic soda drop by drop until the solution becomes nearly colourless, and evaporate carefully to dryness, and ignite to convert the sodium iodate into iodide. (NaIO₃ = NaI + O₃). A white salt is obtained, which is sodium iodide.

(a) Dissolve it in water and add to it about $\frac{1}{4}$ litre of water, then add a little of the starch solution, and observe that no blue colour is produced as in the case

of free iodine. Now add a drop of chlorine water : this will liberate the iodine and the blue colour will be produced ; add more chlorine water, and the colour will disappear, owing to the formation of a chloride of iodine which does not colour starch blue.

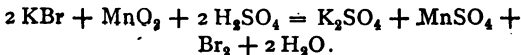
(b) Add a few drops of the sodium iodide solution to some distilled water, then solution of silver nitrate, and observe the pale yellow precipitate of insoluble silver iodide which is produced. Sodium iodide and silver nitrate yield sodium nitrate and silver iodide :



$$150 + 170 = 85 + 235.$$

45. Preparation of bromine.

When sulphuric acid acts upon a mixture of potassium bromide and manganese dioxide, potassium sulphate, manganese sulphate, bromine, and water are produced. Thus :

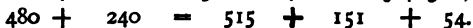


$$238.2 + 87 + 196 = 174.2 + 151 + 160 + 36.$$

Proceed exactly as in the preparation of iodine (42), but substitute potassium bromide for potassium iodide, and keep the receiver very cold. A dark-coloured heavy liquid will be obtained in the receiver : this is bromine. Observe that it is heavier than the water, which always distils over with it, and that it possesses a powerful irritating smell. Observe also that it dissolves in water, forming a red-coloured solution, which possesses bleaching properties.

46. Preparation of sodium bromide.

Bromine is dissolved by a solution of caustic soda and sodium bromide (NaBr), sodium bromate (NaBrO₃) and water are produced. Thus :



Proceed as in the preparation of sodium iodide (44), substituting bromine for iodine. Dissolve the salt obtained in water, and observe that the solution is colourless ; add chlorine water and observe the yellow colour produced by the liberation of bromine.

47. Preparation and properties of hydrofluoric acid.

When sulphuric acid acts upon calcium fluoride (fluor-spar), calcium sulphate and hydrofluoric acid are produced. Thus :



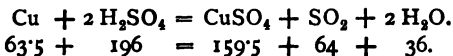
This gas cannot be collected in glass vessels as it combines with the silica of glass, forming silicon tetrafluoride, SiF₄. This property may be observed by covering a glass plate with a thin coating of bees wax, scratching away the wax at certain points, and then exposing the plate to the action of the gas. Place some powdered fluor-spar in a small lead or platinum dish, pour over it some strong sulphuric acid, and heat gently. Observe the fumes of hydrofluoric acid which come off, and then place the waxed glass plate across the dish so as to be exposed to the gas, taking care that the heat applied is not sufficient to melt the wax. Remove the plate after a few minutes, warm it to

soften the wax, which may then be rubbed off, and observe that where the wax was scratched the glass is etched, while the part protected by wax has not been attacked.

Avoid breathing the fumes, as the gas is very irritating to the lungs, and acts powerfully on the skin, producing painful wounds.

48 *Preparation of sulphur dioxide.*

When sulphuric acid acts upon copper, copper sulphate, sulphur dioxide, and water are produced. Thus :



Place some copper turnings in a flask of about half a litre in capacity, provided with a funnel and conducting tube bent twice at right angles. Pour enough strong sulphuric acid down the funnel tube to cover the copper, and apply heat, collecting the gas, which is heavier than air, by downward displacement (see Fig. 10). Fill two jars with the gas, and then allow it to pass, first into a test tube containing nitric acid, and then into one containing a solution of potassium chromate. Observe in the first case the brown vapours of oxides of nitrogen which are given off, and in the second the change of colour from yellow to green. In both cases the sulphur dioxide has acted as a reducing agent, reducing the nitric acid to a lower stage of oxidation, and the potassium chromate to a chromium salt of a green colour ; while in each case the sulphur dioxide is oxidized to sulphuric acid, as may be seen

PROPERTIES OF SULPHUR DIOXIDE. 37

by adding barium chloride, which will precipitate white barium sulphate, insoluble in hydrochloric acid.

49. *Properties of sulphur dioxide.*

(a) Sulphur dioxide does not support combustion, and reddens litmus solution.

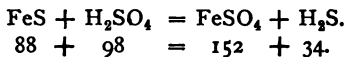
Place a lighted taper in a jar of the gas and observe that it is at once extinguished. Then add a solution of litmus, and observe the bright red colour produced.

(b) Sulphur dioxide is extremely soluble in water.

Invert a jar of the gas in the pneumatic trough, and observe the rapid rise of water inside the jar, produced by the absorption of the gas.

50. *Preparation of sulphuretted hydrogen.*

When sulphuric acid acts upon ferrous sulphide, ferrous sulphate and sulphuretted hydrogen are produced. Thus :



Place a few pieces of ferrous sulphide in a small flask provided with a funnel and conducting tube, the latter of which passes air-tight into a small flask containing water (to collect any impurities which may pass over), and having a second tube fitted into it and bent so as to pass into a flask containing water (see figure). Now cover the ferrous sulphide with a layer of water, and add a few drops of strong sulphuric acid: observe the effervescence which soon begins, and the disagreeable and characteristic smell which the water in the flask soon possesses from

the solution of the gas in it. When the water smells strongly, remove the flask; then decant off the acid from the ferrous sulphide, wash it two or three times with water, retaining it in the flask so that it may be used again by simply adding fresh acid.

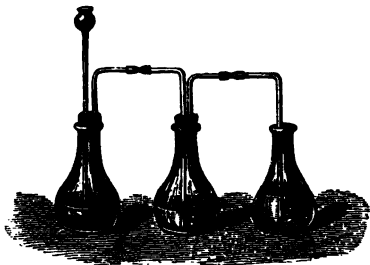
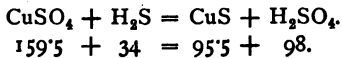


FIG. 12.

51. *Properties of sulphuretted hydrogen.*

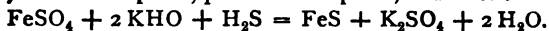
Sulphuretted hydrogen precipitates the solutions of salts of certain metals in an acid solution, others in an alkaline solution, and does not, under any circumstances, precipitate the remainder; thus, solutions of copper salts are precipitated in an acid solution, solutions of iron salts in an alkaline one, and solutions of sodium salts are not precipitated at all. Thus:

Copper sulphate and sulphuretted hydrogen yield copper sulphide and sulphuric acid:



PREPARATION OF CAUSTIC SODA. 39

Iron sulphate and potash and sulphuretted hydrogen yield iron sulphide, potassium sulphate, and water.

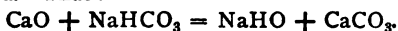


$$152 + 112 \cdot 2 + 34 = 88 + 174 \cdot 2 + 36.$$

Place in a test glass a solution of copper sulphate, in another a solution of iron sulphate, and in a third a solution of sodium chloride; to each add a few drops of hydrochloric acid, and then a little sulphuretted hydrogen water. Observe the black precipitate of copper sulphide in the first glass, and no precipitate in the other two glasses. To each of these add a little potash solution, and observe the black precipitate of ferrous sulphide in the one case, and the absence of a precipitate in the other.

52. Preparation of sodium hydrate (caustic soda).

When caustic lime is added to a solution of sodium bicarbonate, caustic soda and calcium carbonate are produced. Thus :



$$56 + 84 = 40 + 100.$$

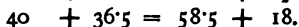
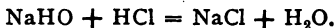
Dissolve about 40 grams of sodium bicarbonate in about half a litre of hot water. Then weigh out 30 grams of quick lime, slake it with water, and when it is thoroughly slaked, stir it up with more water so as to obtain a milky fluid having lime in suspension. Add this to the hot solution of sodium bicarbonate, and boil for a few minutes. Withdraw the lamp, allow the precipitate to subside, and observe if a small portion of the clear liquid effervesce when hydrochloric acid is added to it. If so, there is still some sodium

bicarbonate unconverted into caustic soda, and more lime must, therefore, be added. If, on the other hand, no effervescence occurs, the decomposition is complete, and the clear liquid is then evaporated in a clean iron or silver dish to dryness. The resulting white substance is sodium hydrate (NaHO) or caustic soda.

53. Properties of sodium hydrate.

Sodium hydrate is a powerful alkali, and turns red litmus solution blue. When hydrochloric acid is added to it, it is neutralized, and sodium chloride (common salt) formed. (See 39.)

Sodium hydrate and hydrochloric acid yield sodium chloride and water :



Dissolve some of the caustic soda obtained in 52, in water, and add to it a solution of reddened litmus, and observe the change in colour from red to blue. Dissolve a second portion in water, and add to it hydrochloric acid by degrees, until a drop of the liquid taken out on a glass rod ceases to colour litmus paper blue. On evaporating the liquid thus obtained to a small bulk, sodium chloride will separate out.

PART II.

BLOW-PIPE ANALYSIS.—PRELIMINARY
EXAMINATION.**54. Blow-pipe reactions.**

How to use the blow-pipe.*

Close the holes at the foot of the Bunsen lamp (Fig. 13) so as to exclude air, and thus obtain a luminous flame. Now place the nozzle of the blow-pipe in the centre of the flame, and blow gently through the tube : observe that the flame produced is blue and corresponds to the non-luminous flame of the Bunsen lamp. This is the *oxidizing* or *outer* flame of the blow-pipe.

Now hold the nozzle of the blow-pipe *just outside* the luminous gas flame, and blow gently: observe that the flame is partly yellow. This is the *reducing* or *inner* flame of the blow-pipe (Fig. 14).

The oxidizing flame is used when a substance has to be oxidized, the reducing flame when a body has to be reduced, *e.g.* from a salt to the metallic state.

* The student should be shown, once for all, the different uses of the blow-pipe, and then be allowed to practise on several different substances.

EXAMPLES.

1. *Reduction*.—Mix together in a mortar equal small quantities of dry sodium bicarbonate and silver nitrate. Place a portion in a little hollow scooped out of a



FIG. 13.



FIG. 14.

sound piece of charcoal, and heat in the *reducing* flame of the blow-pipe. Observe the bright metallic bead of silver obtained, dissolve it in nitric acid, and precipitate it as chloride with a few drops of HCl.

2. *Oxidation*.—(a) Make a small loop on the end of a piece of platinum wire, heat it, and dip it while hot in some sodium bicarbonate, so as to cause a small quantity to adhere to the wire; now heat it with the blow-pipe flame until it is fused.* Then place on it a minute quantity of any manganese compound, and heat again in the *oxidising* flame of the blow-pipe; by

* In a similar way, beads are also made with borax or microcosmic salt, instead of sodium bicarbonate.

this means sodium manganate is formed, which colours the bead bright green.

(b) Heat a small portion of metallic lead on a piece of charcoal in the oxidizing blow-pipe flame. Observe the yellow incrustation on the charcoal produced by the *oxidation* of the lead to litharge (PbO).

55. Blow-pipe reactions for the commonly occurring metals.*

(a) Compounds reduced to metal when heated with NaHCO_3 on charcoal in reducing flame :

Silver.	Lead.	Bismuth.	Antimony.
Malleable beads.		Brittle beads.	

(b) Compounds reduced to metal when heated with a mixture of KCN and NaHCO_3 in reducing flame :

Tin.	Copper.
White.	Red.

(c) Compounds reduced to metal when heated on charcoal with reducing agents, but which at once volatilize :

Mercury.	Arsenic.
-----------------	-----------------

(d) Compounds reduced to magnetic metallic powders when heated on charcoal with reducing agents :

Iron.	Nickel.	Cobalt.
--------------	----------------	----------------

(e) Compounds reduced to metal when heated on charcoal with reducing agents, but which are at once converted into oxides :

Cadmium.	Zinc
Oxide is brown.	Oxide is white.

* These reactions must be carried out *in the order indicated* if they are applied to the examination of an unknown compound, since a metallic salt which is reduced by NaHCO_3 alone, is reduced *a fortiori* by a mixture of KCN and NaHCO_3 .

(*f*) Compounds which, after being heated on charcoal, then moistened with CoCl_2 , and heated again, yield characteristic colours :

Zinc.	Aluminium.	Magnesium.
Green.	Blue.	Pink.

(*g*) Compounds which when fused in a borax bead impart to it a characteristic colour :

Iron.	Cobalt.	Nickel.	Manganese.	Chromium.	Copper.
Yellow.	Blue.	Reddish yellow.	Amethyst.	Green.	Blue.

(*h*) Compounds which impart a characteristic colour to any non-luminous flame :

Barium.	Strontium.	Calcium.	Potassium.	Sodium.
Green.	Crimson.	Red.	Violet.	Yellow.

56. Having found out *approximately* by these reactions what the substance is, proceed to apply the following

Confirmatory Tests.

(*a**) Silver bead soluble in HNO_3 . Solution yields with HCl white curdy precipitate of AgCl .

Lead bead soluble in HNO_3 . Solution yields with H_2SO_4 heavy white precipitate of PbSO_4 .

Bismuth bead soluble in HNO_3 . Solution evaporated with HCl yields with H_2S *black* precipitate of Bi_2S_3 .

Antimony bead soluble in HNO_3 . Solution evaporated with HCl yields with H_2S *orange* precipitate of Sb_2S_3 .

(*b*) Tin bead soluble in HNO_3 . Solution on evaporation yields white precipitate of SnO_2 .

* The letters correspond with those in the preceding paragraphs.

Copper bead soluble in HNO_3 . Solution, on addition of $(\text{NH}_4)\text{HO}$ in excess, yields deep blue solution.

(c) Mercury compounds, when heated in a small bulb-tube with NaHCO_3 , yield the metal in minute globules.

Arsenic compounds, when heated in a small bulb-tube with $\text{KCN} + \text{NaHCO}_3$ yield the metal as a shining mirror.

(d) Iron powder soluble in $\text{HNO}_3 + \text{HCl}$ yields yellow solution which gives a deep blue coloration with $\text{K}_4\text{Fe}(\text{CN})_6$.

Cobalt powder soluble in HNO_3 yields red solution, which gives a blue bead when fused with borax.

Nickel powder soluble in HNO_3 yields green solution, which gives a reddish yellow bead when fused with borax.

(e) Cadmium oxide distinguished by its brown colour on the charcoal.

Zinc oxide distinguished by its yellow colour while hot, turning white when cold. (See also under *f*.)

(f) Zinc compounds, a green residue on charcoal when moistened with CoCl_2 and re-heated. (See also under *e*.)

Aluminium compounds, a blue residue on charcoal when moistened with CoCl_2 and re-heated.

Magnesium compounds, a pink residue on charcoal when moistened with CoCl_2 and re-heated.

} Best seen
when cold.

(g) Iron borax bead, reddish yellow when hot, pale yellow on cooling in oxidizing flame.

Iron borax bead, light green in reducing flame.

Cobalt borax bead, deep blue in either oxidizing or reducing flame.

Nickel borax bead, reddish yellow when hot, paler on cooling, and finally nearly colourless in oxidizing flame.

Nickel borax bead, grey when heated in the reducing flame.

Manganese borax bead, amethyst-coloured in reducing flame, colour disappears in oxidizing flame.

Chromium borax bead, green in either oxidizing or reducing flame.

Copper borax bead, blue or greenish-blue in the oxidizing flame, becomes colourless in the reducing flame. (See also under *b*.)

(*h*) Barium salts colour the non-luminous gas flame *pale green*.

Strontium salts colour the non-luminous gas flame *bright crimson*.

Calcium salts colour the non-luminous gas flame *dull red*.

Potassium salts colour the non-luminous gas flame *violet*.

Sodium salts colour the non-luminous gas flame *yellow*.

Best seen
after
moistening
the salt
with HCl.

BUNSEN'S FLAME REACTIONS.

57.—The flame of an ordinary Bunsen lamp serves for nearly all the reactions which can be performed by the mouth blow-pipe. It is most convenient to use a

lamp in which the admission of air can be regulated, and in which the flame is kept steady by a conical chimney supported from the tube of the lamp (see Fig. 15). Adjust the brass cap covering the holes *d d*,

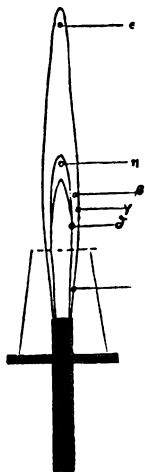


FIG. 15.

Fig. 13, so as to obtain a small luminous point at η , Fig. 15, and then notice the following zones of flame, and the purposes to which they are best suited.

a. Temperature low. Suitable for observing flame colorations of volatile substances.

β. Highest temperature. Suitable for fusions at high temperatures.

γ. The lower oxidizing flame. Suitable for oxidation of substances in borax or other beads.

δ. The lower reducing flame. Suitable for reductions on charcoal, and in fused borax or other beads.

ε. The upper oxidizing flame (obtained by admitting the maximum of air). Suitable for oxidation at lower temperatures than are found at β and γ .

η. The upper reducing flame. Suitable for reductions ; possesses greater reducing power than δ

Metallic films.—The more volatile metals, such as arsenic, mercury, and zinc, are reduced from their compounds when these are heated on an asbestos thread in the upper reducing flame (η). If a small porcelain basin, filled with cold water, be held just above the substance to be examined, the volatilized metal condenses on the cold basin as a metallic film.

Example.—Place a minute quantity of any arsenic compound on a thread of asbestos. Hold this in one hand, and in the other a small porcelain basin filled with cold water. Now place the basin just above the upper reducing flame, and then the asbestos thread immediately below. In a few seconds the reduction will be complete ; remove the basin and observe the brown film of metallic arsenic. Moisten the film with cold dilute nitric acid, and observe that it is scarcely soluble ; moisten now with solution of sodium hypochlorite, and observe its instant solubility.

Metallic beads.—The less volatile metals may be

obtained as beads, when their compounds are heated with sodium carbonate on a small charcoal rod held in the lower reducing flame (δ).

Example.—Hold a crystal of sodium carbonate in the lamp flame for a few seconds till it begins to fuse ; then rub the fused salt thus obtained over a common wooden lucifer match, and burn this until it is converted into a rod of charcoal. Then allow a single drop of the fused sodium carbonate to fall on the palm of the hand, mix this intimately by means of a pen-knife with a small quantity of silver nitrate, and then place a very small portion of the mixture on the point of the rod of charcoal. Allow the mixture to melt in the lower oxidizing flame (γ), and then push the charcoal splinter into the lower reducing flame (δ). When the reduction is completed, remove the splinter and examine the point with a lens. Minute beads of fused silver will be seen, which may be further examined by breaking off the end of the splinter, and crushing it, along with a few drops of water in a small agate mortar. Pour off the water (which will carry the charcoal with it), and examine the metal thus obtained in the same way as the bead obtained by the mouth blow-pipe (**56, a**).

58. Compounds of the following metals form metallic films :—ANTIMONY, ARSENIC, BISMUTH, MERCURY, THALLIUM, CADMIUM, ZINC, INDIUM, and LEAD. They may be further distinguished by the following tests :—

Antimony.	Black film, thin part brown	} Scarcely soluble in cold dilute HNO_3 .
Arsenic.	" " "	
Bismuth.	Black film, thin part brown	} With difficulty soluble in cold dilute HNO_3 .
Mercury.	Grey non-coherent thin film	
Thallium.	Black film, thin part brown	
Cadmium.	Black film, thin part brown	} Instantly soluble in cold dilute HNO_3 .
Zinc.	" " "	
Indium.	" " "	
Lead.	" " "	

Compounds of the following metals give no film, but are reduced to metal on charcoal splinter :—
COPPER, TIN, SILVER, GOLD, PLATINUM, IRON, NICKEL, and COBALT. They may be further distinguished as follows :—

Copper.	Red bead, soluble in HNO_3	} Fusible to metallic beads.
Tin.	White bead " "	
Silver.	" " "	
Gold.	Yellow bead, insoluble "	
Platinum.	Non-magnetic powder	} Not fusible to beads, but obtained as metallic powders.
Iron.	Magnetic powder	
Nickel.	" "	
Cobalt.	" "	

59. Additional tests for the compounds of the following metals ;—

Antimony.—On asbestos thread in upper reducing flame, pale green coloration, unaccompanied by smell. Reduced on charcoal splinter, yields white brittle metallic beads.

Arsenic.—On asbestos thread in upper reducing flame, pale blue coloration, and characteristic smell (garlic). Reduced on charcoal splinter, yields no metallic bead.

Bismuth.—Reduced on charcoal splinter, yields shining yellowish brittle splinters of metal. Dissolve in HNO_3 , add SnCl_2 , and NaHO , yields black precipitate of Bi_2O_3 .

Mercury.—Mixed with dry sodium carbonate and potassium nitrate, in a small thin test-tube (5 millimetres wide and 15 millimetres long), and held in the flame (by a platinum wire coiled round it) just below a small porcelain basin filled with water, yields grey film, which, on rubbing with a piece of filter paper, is collected into small globules. If the quantity of mercury be large, globules form at once.

Thallium.—Flame coloration bright green. Reduced on charcoal splinter, yields white ductile bead, which quickly oxidizes, and is acted on by HCl with difficulty.

Cadmium.—Reduced on charcoal splinter imperfectly to a white ductile bead.

Zinc.—On asbestos thread in upper oxidizing flame, yields white film of ZnO on the porcelain basin. Moisten a square centimetre of filter paper with HNO_3 , and rub it over the surface of the basin so as to dissolve the oxide film; roll this up and place it in a coil of thin platinum wire. Now burn the paper in the upper oxidizing flame at as low a temperature as possible, and observe that the colour of the ash is

yellow, while hot, and white on cooling. Moisten his ash with a drop of a very dilute solution of cobalt, heat in the lamp flame, and observe the green colour produced.

Indium.—Flame coloration, intense indigo colour. Reduced on charcoal splinter with difficulty to silver-white ductile globules, slowly soluble in HCl.

Lead.—Reduced on charcoal splinter, yields soft ductile metallic beads, soluble in HNO_3 . Add H_2SO_4 , yields white precipitate of PbSO_4 .

Copper.—Reduced on charcoal splinter, yields ductile metallic beads of a red colour. Dissolve in HNO_3 and add $\text{K}_4\text{Fe}(\text{CN})_6$, yields chocolate coloured precipitate of $\text{Cu}_2\text{Fe}(\text{CN})_6$.

Fuse a small quantity of borax on a straight piece of platinum wire (of the thickness of a horsehair), and, having obtained a clear bead, add a trace of any copper compound, and observe the blue bead obtained, which does not alter in the lower reducing flame. Add a trace of tin or any tin salt, and heat in the lower reducing flame; observe the change of colour to red, owing to the formation of Cu_2O .

Tin.—Obtain a borax bead coloured faintly blue by copper, and add the tin compound; proceed just as described under copper. The change of colour from blue to red indicates presence of tin.

Silver.—Reduced on charcoal splinter, yields white ductile beads. Dissolve in HNO_3 and add HCl, yields white curdy precipitate of Ag Cl.

Gold.—Reduced on charcoal splinter, yields yellow

very malleable beads. Dissolve in *aqua regia*, absorb the yellow solution on filter paper, and moisten with SnCl_2 , yields purple of Cassius.

Platinum.—Reduced on charcoal splinter yields a grey spongy mass, which becomes lustrous when rubbed in the mortar. Observe insolubility in HCl and in HNO_3 , and solubility in *aqua regia*, forming a light yellow solution.

Iron.—Reduced on charcoal splinter, yields no bead, but minute metallic particles. Crush the end of the splinter in an agate mortar with a little water, and stir gently with a magnetized knife-blade. The finely divided metal will adhere to the knife. Rub this off on filter-paper, dissolve in *aqua regia* and add $\text{K}_4\text{Fe}(\text{CN})_6$: observe the blue coloration from formation of Prussian blue.

Borax bead: In the oxidizing flame when hot,
yellow to brownish red.

„ „ In the oxidizing flame when cold,
yellow to brownish yellow.

„ „ In the reducing flame, bottle
green.

Nickel.—Reduced on charcoal splinter, yields white lustrous ductile particles, which form a brush on the point of the magnetized knife-blade. Rub these on paper and dissolve in HNO_3 , and observe the green colour produced.

Borax bead: In the oxidizing flame, greyish brown or dirty violet.

Upper reducing flame, grey from reduced nickel,

which often collects to a spongy mass, leaving the bead colourless.

Cobalt.—Reduced on charcoal splinter, yields white lustrous ductile particles, which adhere to the magnetized knife-blade. Rub these on paper and moisten with HNO_3 : observe the red colour, which changes to green on addition of HCl and drying; moisten with water, and observe the disappearance of the colour.

Borax bead: In the oxidizing flame, bright blue, unaltered in the lower reducing flame.

60. The following metals are most easily recognized as compounds:—CHROMIUM, MANGANESE, URANIUM.

Chromium.—Heated on platinum foil with Na_2CO_3 and with repeated additions of KNO_3 , yields a yellow mass soluble in water to a yellow solution.

Manganese.—Borax bead amethyst-coloured in the oxidizing flame, colourless bead in the reducing flame. Heated with Na_2CO_3 and KNO_3 , yields a green bead, soluble in water to a green solution, which turns red on addition of acetic acid.

Uranium.—Borax bead yellow, in the oxidizing flame, which becomes green in the reducing flame, especially on addition of SnCl_2 .

The following tests for phosphorus and sulphur compounds are exceedingly delicate:—

Phosphorus.—Ignite the sample, and then powder finely and place in a small test tube about the thickness of a straw, along with a piece of magnesium wire

about five millimetres long, which should be covered by the powder. Now heat, and observe the incandescence caused by the formation of magnesium phosphide. Moisten the residue, and observe the highly characteristic smell of phosphuretted hydrogen.

Sulphur. — Reduced on charcoal splinter with Na_2CO_3 , yields Na_2S . Break off the charcoal point, place it on a silver coin, and moisten with a drop of water. The silver is at once blackened, owing to the formation of silver sulphide.

61.—PRELIMINARY EXAMINATION OF SINGLE SALTS.

Before proceeding to the systematic analysis of single salts or mixtures, it is always advantageous to subject substances to a *preliminary examination*, in order to ascertain the probable nature of the substance. The tables A and B, which follow, are adapted for the detection of single salts, either soluble or insoluble.

White and soluble in HCl indicates **Phosphates, Silicates, Oxalates, Borates, and Fluorides**. Also **Carbonates and Sulphites** (see *c*).

Yellow indicates **Chromates** (see *c*).

If Ba Cl₂ has given no precipitate, add Ag NO₃ to another portion of the solution, and observe if a precipitate form.

White indicates **Chlorides**. Also **Cyanides** (see *c*).

Yellowish-white, **Bromides and Iodides**.

Black indicates **Sulphides** (see *c*).

- (*g*) If neither water nor HCl has dissolved the substance, try nitric acid; and if this does not dissolve it, try *aqua regia*; and if that does not dissolve it, examine it according to the methods described in the following table (B).

NOTE.—If the substance is dissolved in H NO₃ or aqua regia, it must be evaporated to dryness with HCl before proceeding to the examination for base (*β*).

β. EXAMINATION FOR BASE.

A solution having been obtained, observe—

- (*k*) If H Cl produce a precipitate, it indicates—
Silver, Lead, or Mercurous Salts.
- (*i*) If H Cl + H₂S produce a precipitate, it indicates—
Mercuric Salts, Lead, Bismuth, or Copper (black).
Arsenic, Stannic Salts, or Cadmium (yellow).
Antimony (orange).
Stannous Salts (brown).
- (*j*) If (NH₄) HO + NH₄ Cl + (NH₄)₂S produce a precipitate, it indicates—
Iron, Nickel, or Cobalt (black).
Zinc or Aluminium (white).
Manganese (flesh-coloured).
Chromium (green).
- (*h*) If (NH₄) HO + NH₄Cl + (NH₄)₂ CO₃ produce a precipitate, it indicates—
{ **Barium** (tinges flame green).
{ **Strontium** (" " crimson).
{ **Calcium** (" " dull red).
- (*l*) If not precipitated by the above reagents, it indicates—
{ **Magnesium**, precipitated by Na₂ HPO₄ (white).
{ **Potassium** (tinges flame violet).
{ **Sodium** (" " yellow).
Ammonium Salts (heated with NaHO gives smell of NH₃).

TABLE B.

EXAMINATION OF INSOLUBLE SUBSTANCES.

The following substances are, under certain circumstances, insoluble in acids, and must be examined specially:—**Silica, Silicates, Alumina, Aluminates, Oxides of Antimony, Chromium, and Tin, Chrome Iron Ore, Sulphates of Barium, Strontium, and Lead, certain Fluorides** (*e.g.* of Calcium), **certain Sulphides** (*e.g.* of Lead), the **Chloride, Bromide, and Iodide of Silver, Carbon, and Sulphur.**

Heat the substance in a dry tube, and observe whether—

- (a) It fuses and volatilizes completely. **Sulphur** (smells of SO_2).
- (b) It fuses, but does not volatilize. **Chloride, Bromide, or Iodide of Silver.** (Yields metallic silver on fusing on charcoal with Na_2CO_3).
- (c) It is infusible, but disappears on heating. **Carbon** (Deflagrates when heated with KNO_3).
- (d) It is infusible, but darkened in colour while hot, regaining its colour on cooling. **Tin Dioxide and Antimony Pentoxide.** (Confirm by blow-pipe test—tin bead is malleable; antimony bead brittle.)

Observe whether—

- (e) It yields a green bead with borax or microcosmic salt. **Chromium Oxide or Chrome Iron Ore.**
- (f) It swims undissolved in a bead of microcosmic salt. **Silica and Silicates.** (Fuse with four times its weight of a mixture of K_2CO_3 and Na_2CO_3 . Allow to cool, dissolve in water, add HCl , and evaporate to dryness. Silica will separate out as a gelatinous mass.)
- (g) It yields a colourless bead, with microcosmic salt. **Alumina.** (Heated on charcoal and moistened with $\text{Co}(\text{NO}_3)_2$ and re-heated, it yields a blue infusible mass.)
- (h) It is white and infusible, but quite unaltered by heating. **Lead Sulphate** yields, when heated with Na_2CO_3 in blow-pipe reducing flame, malleable metallic bead. (See also i.)

Barium Sulphate, fused with Na_2CO_3 and H Cl added, yields Ba Cl_2 (flame coloration, green), precipitated by Sr SO_4 solution.

Strontium Sulphate, fused with Na_2CO_3 and HCl added, yields Sr Cl_2 (flame coloration, crimson), precipitated by Ca SO_4 solution.

Calcium Fluoride, heated with H_2SO_4 , yields H F , which etches glass.

- (i) It is black and infusible, and yields a malleable metallic bead when fused with Na_2CO_3 in the blow-pipe flame. **Lead Sulphide**. (Bead leaves black mark on paper; and, when dissolved in H NO_3 , gives a white precipitate on addition of H_2SO_4 .)

PART III.

REACTIONS OF THE COMMONLY OCCUR- RING METALS, WITH THE METHODS OF THEIR SEPARATION.

GROUPING OF THE METALS.

62. The metals are divided into five groups according to their behaviour with certain substances which are termed *group reagents*. These five groups are the following :—

GROUP I.—(SILVER GROUP.)*

Group reagent, HCl.

Silver, Mercury, Lead.

The chlorides of the metals of this group are insoluble in water, and are therefore precipitated on addition of HCl.

* A characteristic metal in each group may conveniently be used to designate that group. Thus, we may say, "Silver Group" and "Copper Group," in place of Groups I. and II.

GROUP II. (COPPER GROUP.)

Group reagent, H_2S in presence of HCl .

Mercury, Lead, Bismuth, Copper, Cadmium, Arsenic, Antimony, and Tin.

The sulphides of the metals of this group are insoluble in HCl , and are therefore precipitated by H_2S in an aqueous solution containing HCl . The three last metals, arsenic, antimony, and tin, form a sub-group, as their sulphides are soluble in $(\text{NH}_4)_2\text{S}_2$, whilst the sulphides of the remaining metals are insoluble in that reagent.

GROUP III. (IRON GROUP.)

Group reagent, $(\text{NH}_4)_2\text{S}$, in presence of NH_4Cl and $(\text{NH}_4)\text{HO}$.

Iron, Nickel, Cobalt, Zinc, Aluminium, Manganese, and Chromium.

The sulphides and hydrated oxides of the metals of this group are insoluble in water, and are therefore precipitated on addition of the group reagent. Aluminium and chromium are precipitated as hydrated oxides, the others as sulphides.

GROUP IV. (BARIUM GROUP).

Group reagent, $(\text{NH}_4)_2\text{CO}_3$, in presence of $(\text{NH}_4)\text{HO}$ and NH_4Cl .

Barium, Strontium, Calcium.

The carbonates of the metals of this group are insoluble in water, and are precipitated on the addition of $(\text{NH}_4)_2\text{CO}_3$; as, however, they are soluble in acids, $(\text{NH}_4)\text{HO}$ must be added when the solution is acid.

GROUP V. (POTASSIUM GROUP.)

Metals unprecipitated by the above group reagents.

Magnesium, Potassium, Sodium, Ammonium.

These metals have no common precipitant, and are therefore distinguished by individual tests.

The student should at first have several metallic salts given to him, and be asked merely to determine to which of the above groups each salt belongs; he ought next to make himself familiar with the *individual tests* for each metal which follow, and then proceed to the *separations* of the different metals. It will also be well for him to attempt to frame a table of separations for each group before consulting those given in the book.

Reactions of the Metals of the Silver Group.

63. Metals whose chlorides are insoluble in water, and which are precipitated on addition of the group reagent, HCl :

Silver, Mercury, Lead.

SILVER. Ag, combining weight 108.

1. HCl produces a white curdy precipitate of AgCl, insoluble in hot water and in HNO_3 , but readily soluble in $(\text{NH}_4)\text{HO}$.

2. H_2S or $(\text{NH}_4)_2\text{S}$ produces a black precipitate of Ag_2S , soluble in boiling HNO_3 , with separation of sulphur.

3. NaHO produces a light brown precipitate of Ag_2O , insoluble in excess of NaHO, but soluble in $(\text{NH}_4)\text{HO}$.

4. K_2CrO_4 produces a dark red precipitate of Ag_2CrO_4 , soluble in hot HNO_3 ; this solution deposits on cooling an acid chromate in needle-shaped crystals.

5. Heated on charcoal with Na_2CO_3 , in the reducing flame of the blow-pipe, yields bright, malleable metallic beads, soluble in HNO_3 (**56, a**).

64. MERCURY. Hg, c.w. 200. **Mercurous Salts.**

1. HCl produces a white precipitate of Hg_2Cl_2 (calomel), insoluble in cold HNO_3 , and blackened by $(\text{NH}_4)\text{HO}$, from formation of $\text{Hg}_2\text{Cl}(\text{NH}_2)$.

2. H_2S or $(\text{NH}_4)_2\text{S}$ produces a black precipitate of Hg_2S , not dissolved by boiling HNO_3 .

3. NaHO produces a black precipitate of Hg_2O , insoluble in excess of NaHO or $(\text{NH}_4)\text{HO}$.

4. SnCl_2 produces a grey precipitate of Hg . If the fluid be poured off and the residue boiled with HCl distinct globules are obtained.

5. If a drop of a neutral or only slightly acid solution of a mercurous salt be placed on a bright piece of copper, metallic mercury is deposited and the stain becomes bright on rubbing: it disappears on heating, owing to the volatility of the mercury.

6. Heated in a small tube with NaHCO_3 , yields grey deposit of Hg , which on rubbing appears in distinct globules (59).

65. LEAD. Pb , c.w. 207.

1. HCl produces a white precipitate of PbCl_2 , which is converted into a basic salt on adding ammonia, but without change of appearance. PbCl_2 is soluble in a small quantity of hot water, or in a large quantity of cold water.

2. H_2SO_4 produces a heavy white precipitate of PbSO_4 , soluble in NaHO . In dilute solutions this precipitate appears only on standing; if therefore there is no immediate precipitation, the solution should be concentrated by evaporation. PbSO_4 is soluble in boiling HCl , and the solution on cooling deposits needle-shaped crystals of PbCl_2 .

3. K_2CrO_4 produces a bright yellow precipitate of PbCrO_4 , readily soluble in NaHO , but with difficulty in HNO_3 .

4. KI produces a bright yellow precipitate of PbI_2 , soluble in boiling water; the solution on cooling deposits the salt in brilliant golden hexagonal scales.

5. Heated on charcoal with NaHCO_3 , yields malleable beads, and at the same time a yellow incrustation of PbO on the charcoal (56, a).

TABLE C.
SILVER GROUP (I.).

66. Separation of Silver, Mercury, and Lead.

Add HCl and filter from the precipitated chlorides.

PRECIPITATE.	FILTRATE.
AgCl , Hg_2Cl_2 , PbCl_2 .	Groups II., III., IV. & V.

Wash precipitate twice with cold water, and add washings to filtrate; then twice with hot water, and test part of this for lead with H_2SO_4 . White precipitate indicates **Lead**. Boil the remaining part down to obtain the needle-shaped crystals of PbCl_2 . If lead be found, wash the precipitate free from it with hot water, and treat the residue with *warm* $(\text{NH}_4)\text{HO}$; filter.

RESIDUE.	FILTRATE.
Hg.	Ag.

If the residue is black, this indicates **Mercury**. Dissolve in $\text{HCl} + \text{HNO}_3$ and test with SnCl_2 . Confirm by reduction test (59).

Add HNO_3 . A white precipitate indicates the presence of **Silver**. Confirm with blow-pipe (56, a).

Reactions of the Metals of the Copper Group.

67. Metals whose sulphides are insoluble in HCl and are precipitated in presence of that acid by the group reagent H_2S .

Mercury, Lead, Bismuth, Copper, Cadmium, Arsenic, Antimony, and Tin.

SUB-GROUP A.—Sulphides of the above metals insoluble in $(NH_4)_2S_2$, viz., **Mercury, Lead, Copper, Bismuth, and Cadmium.**

MERCURY. Hg, c.w. 200. **Mercuric Salts.**

1. H_2S produces, when added by degrees, first a white precipitate, which changes to orange, then to brownish red, and finally to a black precipitate of HgS . These successive changes of colour on the addition of H_2S are exceedingly characteristic. This precipitate is insoluble in HCl and in HNO_3 , even on boiling; it is soluble, however, in KHS and in *aqua regia*.

2. KHO produces a yellow precipitate of HgO , which is insoluble in excess of the precipitant, except when added to very acid solutions.

3. $(NH_4)HO$ produces in solutions of $HgCl_2$ a white precipitate of $HgCl(NH)_2$ ("white precipitate").

METALS OF THE COPPER GROUP. 67

4. SnCl_2 produces, when added in small quantities, a white precipitate of Hg_2Cl_2 , but on adding an excess of the reagent, metallic mercury precipitates as a grey powder, and may be united into a coherent globule by boiling with HCl .

5. Reactions 5 and 6 for mercurous salts (64) are also produced with mercuric salts.

68. LEAD. Pb, c.w. 207.

1. H_2S produces a black precipitate of PbS , even in solutions of PbCl_2 , so that a weak solution of a lead salt which has not been precipitated with HCl will be precipitated with H_2S . Hence lead occurs both in the silver and copper groups.

2. Reactions 2, 3, 4, and 5, for lead, in Group I. (65), are also applicable in this group.

69. BISMUTH. Bi, c.w. 210.

1. H_2S produces a black precipitate of Bi_2S_3 , insoluble in KHS and KHO , but soluble in HNO_3 .

2. KHO or $(\text{NH}_4)\text{HO}$ produces a white precipitate, which on boiling becomes yellow (Bi_2O_3); the precipitate is insoluble in excess of either reagent.

3. H_2O , when added in considerable quantity to normal salts of bismuth, produces an immediate white precipitate of a basic salt of bismuth.

Bismuth trichloride is most easily precipitated by H_2O . If another salt of this metal is being examined, it is best to precipitate the oxide first by ammonia;

dissolve it in as little HCl as possible, and evaporate it almost to dryness. On adding water to this solution, a precipitate of BiOCl at once forms, which is insoluble in tartaric acid (compare corresponding reaction with antimony, 74, 4). Solutions of bismuth salts containing much free acid do not give this reaction with H_2O until the excess of acid has been expelled by evaporation.

4. K_2CrO_4 produces a yellow precipitate of $\text{Bi}_2(\text{CrO}_4)_3$, soluble in HNO_3 , and insoluble in NaHO . (Compare reaction for lead, 65, 3.)

5. Heated on charcoal with NaHCO_3 in the reducing flame of the blow-pipe, yields brittle metallic globules; also a slight yellow incrustation of oxide on the charcoal.

70. COPPER. Cu , c.w. 63.5.

1. H_2S produces a black precipitate of CuS , soluble in HNO_3 , but insoluble in KHS , and only slightly soluble in $(\text{NH}_4)_2\text{S}_2$. CuS is also dissolved by KCN , but is insoluble in hot dilute H_2SO_4 .

2. KHO produces a pale blue precipitate of $\text{Cu}(\text{HO})_2$, insoluble in excess of the precipitant. If the KHO be added in excess and the mixture boiled, the precipitate becomes black and loses water.

3. $(\text{NH}_4)\text{HO}$ produces, when added in small quantities, a greenish blue precipitate of a basic salt, soluble in excess to a dark blue solution, which consists of a double basic salt of copper and ammonium.

4. $\text{K}_4\text{Fe}(\text{CN})_6$ produces a brown precipitate of

TESTS FOR COPPER AND CADMIUM. 69

$\text{Cu}_2\text{Fe}(\text{CN})_6$, insoluble in dilute acids, but decomposed by KHO .

5. Fe precipitates copper in the metallic state, from its solutions, especially in presence of a little free acid. The iron ought to be bright and clean.

6. Zn also precipitates copper solutions. If a solution of copper containing a few drops of HCl be placed in a platinum capsule, and a fragment of zinc added, the copper will be precipitated on the platinum as a red coating.

7. Compounds of copper, when heated in the Bunsen lamp flame, impart a green colour to it, especially after addition of AgCl .

8. Mixed with $\text{NaHCO}_3 + \text{KCN}$ and heated on charcoal before the reducing blow-pipe flame, yields bright red metallic particles, soluble in HNO_3 , and giving a deep blue solution on adding $(\text{NH}_4)\text{HO}$.

71. CADMIUM. Cd , c.w. 112.

1. H_2S produces a yellow precipitate of CdS , soluble in HNO_3 , but insoluble in KHS , in $(\text{NH}_4)_2\text{S}$, and in KCN . CdS is dissolved by hot dilute H_2SO_4 . (Compare reaction for copper, 70, 1.)

2. KHO produces a white precipitate of $\text{Cd}(\text{HO})_2$, insoluble in an excess of the precipitant.

3. $(\text{NH}_4)\text{HO}$ also precipitates $\text{Cd}(\text{HO})_2$, but the precipitate is soluble in excess.

4. Heated on charcoal with NaHCO_3 in the reducing blow-pipe flame, yields no metallic bead, but a brown incrustation of CdO .

TABLE D.

72.—COPPER GROUP (II.).

Separation of Mercury, Lead, Bismuth, Copper, and Cadmium (Sub-Group A).

To the filtrate from the Silver Group add an equal bulk of HCl, boil down nearly to dryness, dilute with H_2O , and pass H_2S through the hot solution. Filter.

RESIDUE.	FILTRATE.
HgS, PbS, Bi₂S₃, CuS, CdS, SnS, Sb₂S₃, and As₂S₃.	Groups III., IV., and V.

Wash with hot H_2O containing H_2S , until free from Cl; digest residue with $(NH_4)_2S_2$ for about fifteen minutes. Filter.

RESIDUE.	FILTRATE.
HgS, PbS, Bi₂S₃, CuS and CdS.	Sub-Group B. (Sn, Sb, and As.) (See Table E.)

Wash with hot H_2O till no longer alkaline; add a small quantity of boiling HNO_3 , pouring it on several times. Filter.

RESIDUE.	FILTRATE.
HgS. Dissolve in aqua regia, boil down to expel acid, and test with $SnCl_2$. White precipitate changing to grey indicates Mercury. Confirm by reduction test, or Bunsen's test for mercury (59).	Pb, Bi, Cu, Cd. Add H_2SO_4, and boil down. White precipitate indicates Lead. Filter from $PbSO_4$, and add $(NH_4)HO$ to filtrate. Filter.
RESIDUE.	FILTRATE.
Bi. A white precipitate. Dissolve in HCl, evaporate to a small bulk, and add to H_2O. A white precipitate indicates Bismuth.	Cu, Cd. A blue solution indicates Copper. Adopt Method I. or II.

METHOD I.

Add to the blue solution KCN till colourless; pass a few bubbles of H_2S through the solution. Yellow precipitate indicates **Cadmium**. (Excess of H_2S must be avoided, because traces of mercury may be present.)

METHOD II.

Add HCl till acid; pass H_2S through; filter; wash rapidly and thoroughly, and treat with hot dilute H_2SO_4 . Black residue indicates **Copper**. To filtrate, add H_2S . Yellow precipitate indicates **Cadmium**.

73. SUB-GROUP B.—Sulphides soluble in $(\text{NH}_4)_2\text{S}_2$, viz., those of **Tin**, **Antimony**, and **Arsenic**.

TIN, Sn, c.w. 118. **Stannous Salts.**

1. H_2S produces a dark brown precipitate of SnS , soluble in $(\text{NH}_4)_2\text{S}_2$ (yellow), but nearly insoluble in $(\text{NH}_4)_2\text{S}$ (colourless). From its solution in $(\text{NH}_4)_2\text{S}_2$ it is re-precipitated as SnS_2 (yellow) on adding HCl . SnS is also soluble in KHO , and, on the addition of acids, is re-precipitated as SnS (brown).

2. KHO produces a white precipitate of $\text{Sn}(\text{HO})_2$ soluble in excess of the reagent.

3. $(\text{NH}_4)\text{HO}$ also produces a precipitate of $\text{Sn}(\text{HO})_2$, but not soluble in excess.

4. HgCl_2 produces at first a white precipitate of Hg_2Cl_2 , and on boiling with excess of the reagent, a grey precipitate of Hg .

5. AuCl_3 produces a purple precipitate (purple of Cassius) on addition of a little HNO_3 .

6. Zn produces a precipitate of metallic tin, in shining laminæ or as a spongy mass.

7. Mixed with $\text{NaHCO}_3 + \text{KCN}$ and heated on charcoal in the reducing blow-pipe flame, yields small globules of Sn and a white incrustation of SnO_2 .

Stannic Salts.—1. H_2S produces a yellow precipitate of SnS_2 , soluble in $(\text{NH}_4)_2\text{S}$, in KHO , and in boiling concentrated HCl . It is with difficulty soluble in $(\text{NH}_4)\text{HO}$, and insoluble in $(\text{NH}_4)_2\text{CO}_3$.

2. KHO or $(\text{NH}_4)\text{HO}$ produces a white precipitate of $\text{SnO}(\text{HO})_2$, soluble in an excess of the precipitant.

TESTS FOR TIN AND ANTIMONY. 73

3. Zn produces the same reaction as with stannous salts. (See above.)

4. The blow-pipe reaction for Stannic is the same as for Stannous Salts. (See above.)

74. ANTIMONY. Sb, c.w. 122.

1. H_2S produces in acid solutions an orange precipitate of Sb_2S_3 , soluble in alkaline sulphides, in KHO , in boiling concentrated HCl , but insoluble in $(\text{NH}_4)_2\text{CO}_3$.

2. KHO produces a precipitate of Sb_2O_3 , soluble in excess of the reagent.

3. $(\text{NH}_4)\text{HO}$ produces a precipitate of Sb_2O_3 , insoluble in excess of the reagent.

4. H_2O produces in solutions of SbCl_3 a white precipitate of SbOCl , soluble in tartaric acid : compare corresponding reaction with bismuth (69, 3).

5. Zn, in presence of HCl and platinum, precipitates Sb as a black powder, which adheres to the platinum. This is best done either by placing a strip of Zn and Pt (in contact) in a solution of Sb made acid with HCl , or by placing a similar solution in a platinum capsule and dropping in a piece of Zn. The black stain on the platinum is not dissolved by cold HCl , but is immediately dissolved by warm HNO_3 .

6 (Marsh's Test).—If a solution of Sb be placed in a flask along with Zn and dilute H_2SO_4 , SbH_3 is given off as a gas, which is decomposed by heat, Sb being deposited. The apparatus is arranged as in the figure. *a* is the evolution flask ; *b*, a tube containing

CaCl_2 to absorb moisture ; and *c*, a tube of hard glass attached to the drying tube, which is drawn out to a point at the extreme end, so as to form a jet. When the dilute acid and zinc have been in contact some time, and when the air has been expelled from the flask, the hydrogen evolved is lighted at the jet and a cold porcelain crucible lid is held against the flame ; if a black stain be produced on it, the materials employed

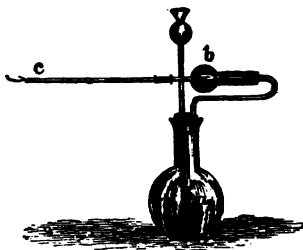


FIG. 16.

are not pure, and must be rejected. Having ascertained that the Zn and H_2SO_4 are pure, add now by the funnel tube a *few drops* of a solution of antimony, and observe that the flame now burns with a bluish green colour, and gives off white fumes (Sb_2O_3), and that on placing a cold porcelain lid against the flame a dull black stain of metallic antimony is deposited on it. Obtain several of these stains in order to compare them with the corresponding arsenic ones, and then heat the tube *c* with the lamp flame. Observe

the deposition of Sb *close to the flame*, and the simultaneous decrease of the green tint of the flame at the jet. Obtain several of these mirrors, observe their silvery lustre, and keep some for comparison with arsenic mirrors.

Further reactions.—(a) Add to the stain on porcelain a drop of NaClO : the stain will remain undissolved.

(b) Cut off with a file the portion of tube containing the metallic mirror, and heat it in a dry test tube. The mirror will be oxidized to Sb_2O_3 , which will deposit as a sublimate on the test tube. Examine this with a lens, and ascertain that it is *amorphous*.

(c) Attach another tube containing an antimony mirror to an apparatus evolving dry H_2S , and warm the mirror gently (heating first the part of the mirror farthest from the evolution flask) : observe the change in colour from the formation of orange Sb_2S_3 . Now detach the tube and pass through it (without heating) a current of dry HCl gas ; the Sb_2S_3 will be converted into SbCl_3 , which is volatile, and may be collected by dipping the end of the tube under water. On adding H_2S to this liquid, orange Sb_2S_3 will be re-precipitated.

7. Allow a current of SbH_3 to pass through a solution of silver nitrate : SbAg_3 will be precipitated (black) and nitric acid left in solution. Filter and dissolve the residue in a hot solution of tartaric acid, add a few drops of HCl , and pass H_2S through the solution : an orange precipitate of Sb_2S_3 will be obtained.

8. Heated with NaHCO_3 on charcoal in the reducing blow-pipe flame, yields brittle globules of the metal,

and a white incrustation of Sb_2O_3 on the charcoal. Fumes of the oxide are also given off after the metal has been removed from the flame, and they occasionally condense round the bead in a crystalline mass.

75. ARSENIC. As, c.w. 75.

1. H_2S produces in acid solutions a yellow precipitate of As_2S_3 , soluble in alkaline sulphides, in KHO , in HNO_3 , and in $(\text{NH}_4)_2\text{CO}_3$, but nearly insoluble in boiling concentrated HCl . (Compare reactions for Sb , 74, 1.)

2. AgNO_3 produces in *neutral* solutions a pale yellow precipitate of Ag_3AsO_3 . This is best obtained by adding first the AgNO_3 solution, and then drop by drop a *very dilute solution* of $(\text{NH}_4)\text{HO}$ prepared by adding one or two drops of ordinary $(\text{NH}_4)\text{HO}$ to a test-tube full of H_2O . The precipitate is readily soluble in excess of $(\text{NH}_4)\text{HO}$, hence the necessity for using a very dilute solution of that reagent.

3. CuSO_4 added under the same conditions as the AgNO_3 , produces a pale green precipitate of CuHAsO_3 (Scheele's green), soluble in $(\text{NH}_4)\text{HO}$.

4. Acetic acid, added to solutions of As_2O_3 and then KHO in slight excess, yields (after evaporation to dryness), on ignition in a small tube, oxide of cacodyl $2(\text{As}(\text{CH}_3)_2)\text{O}$, readily recognized by its powerful and characteristic odour. If SnCl_2 be added to the contents of the tube after ignition, the equally characteristic smell of cacodyl chloride, $\text{As}(\text{CH}_3)_2\text{Cl}$, is observed. These experiments (and also Marsh's test (5))

must be done with an *exceedingly small* quantity of substance, owing to the poisonous properties of the products.

5. Proceed exactly as in Marsh's test for Sb (74, 6), substituting a solution of As for one of Sb, and observe the bluish flame with which the mixture of H and AsH_3 burns, and also the production of white fumes of As_2O_3 . Obtain, as in the case of Sb, stains on porcelain lids, and mirrors by heating the hard glass tube. Compare these with the antimony stains and mirrors, and observe that the latter in the case of As are deposited at a greater distance from the heated part of the tube, owing to the greater volatility of As. Observe also the distinction in colour of the stains: dark brown or almost black in the case of Sb, and, when seen in thin films, pale brown and lustrous in the case of As.

Further reactions.—(a) Add to one of the stains on porcelain a drop of NaClO : it will be rapidly dissolved.

(b) Cut off the portion of tube containing a metallic mirror, and heat it in a dry test tube. The mirror of As will be oxidized to As_2O_3 , which will be deposited in crystals on the cool part of the tube. Examine these with a lens, and observe the octahedral form of the crystals. Take out the piece of tubing which contained the mirror, and dissolve the crystals left in the test-tube in warm H_2O ; add to this solution AgNO_3 and very dilute $(\text{NH}_4)\text{HO}$, and observe the yellow precipitate of Ag_3AsO_3 . Or, to the aqueous solution of

As_2O_3 , add a drop of HCl , and pass H_2S through the solution, and observe the yellow precipitate of As_2S_3 .

(c) Attach another tube containing an arsenic mirror to an apparatus evolving dry H_2S , and warm the mirror gently : it will be converted into yellow As_2S_3 . Now pass dry HCl through the tube (without warming), and observe that the sulphide remains unaltered. (Compare corresponding Sb reactions, 74, 6, c).

(d) Allow a current of AsH_3 to pass through a solution of silver nitrate : a black precipitate of Ag will be produced, and As_2O_3 will be found in solution along with HNO_3 liberated from the AgNO_3 . Filter from the Ag , and very cautiously neutralize the free acid with highly diluted $(\text{NH}_4)\text{HO}$, when a yellow precipitate of Ag_3AsO_3 will be formed. (Compare corresponding Sb reaction, 74, 7.)

6. Compounds of arsenic, when treated with Zn and strong solution of KHO , are converted into AsH_3 by the action of the nascent hydrogen. If this reaction be performed in a test tube, and the gas escaping be held near a piece of paper moistened with AgNO_3 , a bluish black coloration is produced by the formation of AsAg_3 . (Sb compounds give no similar reaction.)

7 (Reinsch's Test).—Add to the solution of arsenic, HCl and a few strips of bright copper wire or foil : As is deposited on the copper, which may be removed from the solution, dried by filter paper, and heated in a dry test-tube to obtain the octahedral crystals of As_2O_3 .

8. Dry reactions.

Place the dry arsenic compound at *a* (Fig. 17), in a drawn-out hard glass tube. Then place above it at *b* a small rod of well-ignited charcoal, and heat the portion containing the charcoal until it is red hot. This will

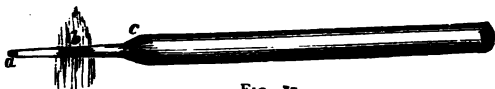


FIG. 17.

cause the glass to soften, and the tube will bend so as to bring the portion *a* into the flame. The arsenic compound will volatilize and be decomposed by the red-hot charcoal, and a metallic mirror will form at *c*.*

9. Place the dry arsenic compound in a bulb tube as at *a* (Fig. 18), along with a mixture of equal parts of *dry* Na_2CO_3 and KCN , and heat the bulb. A mirror

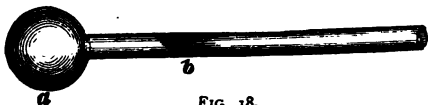


FIG. 18.

of As will form at *b*, which may be further tested by the reactions mentioned for the mirror obtained in Marsh's test (75, 5, *b*). If any moisture be deposited on first heating the tube, remove it by inserting a small coil of filter paper.

10. The above reaction is more delicate when the mixture is heated in a current of dry CO_2 . For this

* Non-volatile compounds of As must be mixed with dry charcoal powder, and heated in a similar tube, having in addition a small bulb at the lower end to contain the mixture.

purpose, the arsenic compound is pounded in a mortar with a perfectly dry mixture of three parts Na_2CO_3 with one part of KCN, and placed at *a* in the tube *ab* (Fig. 19); through which a slow current of *dry* CO_2 is



FIG. 19.

led, and the whole tube *gently* heated until every trace of moisture is expelled. When this is the case the tube is more strongly heated at *a*, and the mirror is obtained at *b*; traces of arsenic escape condensation, and therefore a slight garlic odour is observed at the extremity of the tube. Antimony compounds treated in this way yield no metallic mirror.

11. Arsenic compounds, when mixed with Na_2CO_3 and heated on charcoal by the blow-pipe flame, are reduced to metallic arsenic, which at once volatilizes, and may be recognized by the characteristic odour resembling garlic.

TABLE E.

GROUP II.

76. Separation of Arsenic, Antimony, and Tin (Sub-Group B).

Solution in $(\text{NH}_4)_2\text{S}_2\text{O}_8$ contains sulphides of As, Sb, and Sn. Add HCl until acid: the metals are re-precipitated as sulphides. Filter, wash precipitate with hot water till free from HCl; digest precipitate with one or two pieces of solid $(\text{NH}_4)_2\text{CO}_3$ and H_2O . Filter.

RESIDUE.	FILTRATE.
SnS_2, Sb_2S_3.	As.
Wash and dissolve in strong boiling HCl, dilute with water, and add to the solution a piece of zinc and platinum: Sb forms a black stain on the platinum. Dissolve in HNO_3 , boil down to a small bulk, and pass H_2S through the solution; orange precipitate indicates presence of Antimony . The Sn deposits on the zinc; dissolve in HCl, boil down, and test with HgCl_2 . White precipitate indicates Tin .	Add HCl until acid; wash precipitated sulphide, and dissolve in HCl and a little KClO_3 , boil down to a small bulk, and apply Marsh's test (75, 5). Metallic mirror, yielding octahedral crystals on heating, indicates Arsenic . Dissolve in H_2O , and confirm by adding AgNO_3 and dilute $(\text{NH}_4)\text{HO}$, to obtain yellow precipitate of Ag_3AsO_3 (75, 5 b).

Reactions of the Metals of the Iron Group.

77. Metals whose sulphides and hydrated oxides are insoluble in water, and are precipitated on addition of the group reagent $(\text{NH}_4)_2\text{S}$ in presence of $(\text{NH}_4)\text{HO}$ and NH_4Cl .

Iron, Nickel, Cobalt, Zinc, Aluminium, Manganese, and Chromium.

IRON. Fe, c.w. 56. **Ferrous Salts.**

1. $(\text{NH}_4)_2\text{S}$ produces a black precipitate of FeS , insoluble in alkalis, but soluble in HCl. In dilute solutions of ferrous salts $(\text{NH}_4)_2\text{S}$ produces at first a green colour; on standing, however, FeS separates as a black precipitate.

2. KHO or $(\text{NH}_4)\text{HO}$ produces a white precipitate of ferrous hydrate $\text{Fe}(\text{HO})_2$, which rapidly acquires a dirty green, and ultimately a reddish brown colour, owing to absorption of oxygen and conversion into ferric hydrate $\text{Fe}_2(\text{HO})_6$.

3. Carbonates of the alkalis precipitate FeCO_3

(white), which rapidly darkens in colour owing to absorption of oxygen.

4. $K_4Fe(CN)_6$ produces a white precipitate of $K_2Fe_2(CN)_6$, which rapidly becomes blue by oxidation to $Fe_5(CN)_{12}$ (Prussian blue). It is insoluble in acids, but is decomposed by alkalis.

5. $K_3Fe(CN)_6$ produces a blue precipitate of $Fe_3Fe_2(CN)_{12}$ (Turnbull's blue), also insoluble in acids, but decomposed by alkalis.

6. KCNS produces no coloration.

7. $BaCO_3$ produces no precipitate in cold solutions of ferrous salts.

8. Fused with borax in the oxidizing flame, yellowish red beads are produced; in the reducing flame the beads become green. (See also 59.)

Ferric Salts.—1. H_2S in acid solutions produces a precipitate of sulphur, and the salt is reduced to proto-salt, thus : $Fe_2Cl_6 + H_2S = 2 FeCl_2 + 2 HCl + S$.

2. $(NH_4)_2S$ produces a black precipitate of FeS mixed with sulphur, insoluble in excess of the reagent and in alkalis, but soluble in HCl and in HNO_3 . In dilute solutions of iron only a greenish coloration is produced.

3. KHO or $(NH_4)HO$ produces a brownish red precipitate of $Fe_2(HO)_6$, insoluble in excess of either reagent.

4. $K_4Fe(CN)_6$ produces a precipitate of $Fe_5(CN)_{12}$ (Prussian blue), insoluble in HCl , soluble in $C_2H_2O_4$, and decomposed by KHO or $NaHO$ with separation of $Fe_2(HO)_6$.

5. $K_3Fe(CN)_6$ changes the colour of the solution to reddish brown, but does not produce a precipitate.

6. KCNS produces even in dilute solutions a blood-red coloration, due to the formation of a soluble iron sulphocyanide. HCl does not destroy the coloration, but it is destroyed by $C_2H_3O_2Na$, $HgCl_2$, H_3PO_4 , and by $C_4H_6O_6$.

7. $BaCO_3$ precipitates ferric solutions completely as $Fe_2(HO)_6$ mixed with basic salt.

8. The blow-pipe reactions are the same as for ferrous compounds.

78. NICKEL. Ni, c.w. 58.7.

1. $(NH_4)_2S$ produces a black precipitate of NiS , slightly soluble in excess, forming a brown solution from which NiS is precipitated on boiling. The precipitate is very difficultly soluble in HCl, but dissolves in HNO_3 and in aqua regia.

2. $NaHO$ or KHO produces a light green precipitate of $Ni(HO)_2$, insoluble in excess of the reagent, and unalterable in air.

3. $(NH_4)HO$ produces also a precipitate of $Ni(HO)_2$, readily soluble in excess, yielding a blue fluid, which is re-precipitated by KHO or $NaHO$. Acid solutions, or those containing salts of ammonia, yield no precipitate with $(NH_4)HO$.

4. KCN produces a yellowish green precipitate of $Ni(CN)_2$, soluble in excess to a brownish yellow solution of $2 KCN$, $Ni(CN)_2$. This solution is re-precipitated by addition of dilute HCl or H_2SO_4 , and, if boiled with a strong solution of $NaClO$, yields a black precipitate of $Ni_2(HO)_6$.

5. KNO_3 , in presence of $\text{C}_2\text{H}_4\text{O}_2$, produces no precipitate.

6. Fused with borax in the oxidizing blow-pipe flame, yields reddish yellow beads when hot, which become paler on cooling. In the reducing flame the bead becomes grey by the presence of metallic nickel. (See also 59.)

79. COBALT. Co, c.w. 587.

1. $(\text{NH}_4)_2\text{S}$ produces a black precipitate of CoS , insoluble in excess of the reagent and in HCl , but soluble in aqua regia.

2. KHO or NaHO precipitates blue basic salts, which turn green on exposure to air by oxidation. On heating the precipitate is converted into red hydrate $\text{Co}(\text{HO})_2$, which is soluble in $(\text{NH}_4)_2\text{CO}_3$ to a reddish violet solution.

3. $(\text{NH}_4)\text{HO}$ produces the same precipitate as KHO , soluble in excess, yielding a reddish brown fluid, which is re-precipitated by KHO or NaHO . Acid solutions, or those containing salts of ammonia, are not precipitated.

4. KCN produces a light brown precipitate of $\text{Co}(\text{CN})_2$, soluble in excess of the reagent by formation of 2KCN , $\text{Co}(\text{CN})_2$. This solution is re-precipitated by the addition of HCl or H_2SO_4 . (If the cobalt solution to which KCN is added be acid, a precipitate is produced, soluble in excess of the reagent. When this solution is boiled, potassium cobalti-cyanide $\text{K}_3\text{Co}(\text{CN})_6$ is formed which is not re-precipitated by HCl or H_2SO_4 , nor by NaClO .)

5. KNO_3 added to cobalt solutions with addition of acetic acid, produces on standing in a warm place a yellow crystalline precipitate (double nitrite of potassium and cobalt).

6. Fused with borax in either blow-pipe flame, yields deep blue beads, which are almost black if the quantity of Co be large. (See also 59.)

80. ZINC. Zn, c.w. 65·2.

1. $(\text{NH}_4)_2\text{S}$ produces a white precipitate of ZnS , insoluble in excess of the reagent and in KHO , but soluble in the mineral acids.

2. KHO or NaHO produces a white precipitate of $\text{Zn}(\text{HO})_2$, soluble in excess of either reagent and in $(\text{NH}_4)\text{HO}$. This solution is re-precipitated by diluting and boiling, but is not precipitated by addition of NH_4Cl .

3. Na_2CO_3 produces a white precipitate of basic carbonate, insoluble in excess of the reagent.

4. $(\text{NH}_4)_2\text{CO}_3$ also precipitates the basic carbonate, but it is soluble in excess of the reagent.

5. Heated on charcoal with Na_2CO_3 in the reducing blow-pipe flame, a yellow incrustation of ZnO is obtained, which becomes white when cold.

6. Heated on charcoal by the blow-pipe flame after moistening with CoCl_2 solution, an infusible green mass is obtained. (See also 59.)

81. ALUMINIUM. Al, c.w. 27·4.

1. $(\text{NH}_4)_2\text{S}$ produces a white flocculent precipitate of $\text{Al}_2(\text{HO})_6$.

2. KHO or NaHO produces also a precipitate of $\text{Al}_2(\text{HO})_6$, soluble in acids, even in hot acetic acid and in excess of the reagent. This solution is not precipitated by H_2S , but is re-precipitated by NH_4Cl , or by adding $(\text{NH}_4)\text{HO}$ after acidifying with HCl .

3. $(\text{NH}_4)\text{HO}$ also precipitates $\text{Al}_2(\text{HO})_6$, soluble in a very large excess of the reagent, more difficultly soluble in presence of salts of ammonia.

4. BaCO_3 produces a precipitate of $\text{Al}_2(\text{HO})_6$ mixed with basic salt.

5. Na_2HPO_4 precipitates aluminium phosphate, insoluble in $(\text{NH}_4)\text{HO}$ and in NH_4Cl , but soluble in KHO or NaHO, and in acids. It does not, however, dissolve in hot acetic acid like aluminium hydrate.

6. Heated on charcoal in the blow-pipe flame, then moistened with CoCl_2 , and re-heated, an infusible blue mass is obtained.

82. MANGANESE. Mn, c.w. 55.

1. $(\text{NH}_4)_2\text{S}$ produces a flesh-coloured precipitate of MnS , soluble in acids, even in acetic acid.

2. KHO or NaHO produces a dirty-white precipitate of $\text{Mn}(\text{HO})_2$, insoluble in excess of the reagent; the precipitate rapidly darkens in colour by absorption of oxygen. The freshly-precipitated hydrate is dissolved by NH_4Cl , but the higher oxide is insoluble.

3. $(\text{NH}_4)\text{HO}$ produces the same precipitate of $\text{Mn}(\text{HO})_2$, insoluble in excess of the reagent; but it gives no precipitate if the manganese solution contain NH_4Cl . Such a solution on standing precipitates the dark brown hydrate.

4. Na_2CO_3 produces a white precipitate of MnCO_3 , which darkens in colour by absorption of oxygen.

5. If any manganese solution (free from chlorine) be treated with PbO_2 and then boiled with HNO_3 , it is converted into permanganate, which is recognized by its pink colour as soon as the mixture has settled.

6. If any manganese compound be fused on platinum foil with Na_2CO_3 and a trace of KNO_3 , it is converted into Na_2MnO_4 , recognized by its bright green colour.

7. Fused with borax in the oxidizing flame, an amethyst-coloured bead is obtained, which becomes colourless in the reducing flame.

83. CHROMIUM. Cr, c.w. 52.2.

1. $(\text{NH}_4)_2\text{S}$ produces a bluish green precipitate of $\text{Cr}_2(\text{HO})_6$, insoluble in excess of the reagent.

2. $(\text{NH}_4)\text{HO}$ also precipitates the hydrate, soluble to some extent in excess, yielding a pink fluid, but on heating the precipitation is complete.

3. KHO or NaHO precipitates also $\text{Cr}_2(\text{HO})_6$, soluble however in excess, yielding a green or bluish violet solution. On continued boiling or addition of NH_4Cl and heating, the hydrate is re-precipitated.

4. BaCO_3 produces a precipitate of $\text{Cr}_2(\text{HO})_6$ along with basic salt; the precipitation is not complete till the mixture has stood some time.

5. Fused with Na_2CO_3 and KNO_3 on platinum foil, yellow Na_2CrO_4 is obtained.

6. Fused with borax in either flame (but best in the reducing flame), green beads are obtained.

TABLE

84. IRON GROUP (III.).—Separation of Iron, Nickel,

To the filtrate from the sulphides of the Cu and As groups add $(\text{NH}_4)\text{HO}$ and shake for some time. Filter (preferably by the Bunsen pump). Wash the precipitate with cold

RESIDUE.

NiS and CoS.

Test for Co by borax bead. Dissolve the black residue in HCl and KClO_3 . Boil down just to dryness, dilute with H_2O , add KCN in excess, then a drop of acetic acid, boil for a few minutes, add NaClO in excess, and boil again. A black precipitate indicates **Nickel**. The filtrate from this precipitate may be tested for Co by evaporating to dryness, and fusing in a borax bead. Blue colour indicates **Cobalt**.

METHOD I. Cr IS ABSENT.

Boil down with a little KClO_3 till it smells of Cl . Add pure NaHO till strongly alkaline. Filter.

RESIDUE.

FILTRATE.

 $\text{Fe}_2(\text{HO})_6, \text{Mn}(\text{HO})_2$.

Wash with hot H_2O , dissolve in HCl , add $(\text{NH}_4)\text{HO}$, and filter.

RESIDUE.

FILTRATE.

 $\text{Fe}_2(\text{HO})_6$.

Dissolve in HCl . Test with $\text{K}_4\text{Fe}(\text{CN})_6$. Blue precipitate indicates **Iron**. To ascertain whether the iron is present as ferrous or ferric salt, the *original solution* must be tested with $\text{K}_4\text{Fe}(\text{CN})_6$ and $\text{K}_3\text{Fe}(\text{CN})_6$.

Mn.

Boil down and ignite, to expel salts of ammonium. Fuse with NaHO and KNO_3 . A green residue indicates **Manganese**. Traces of **Ni** and **Co** are found along with the **Mn**.

Al, Zn.

Divide into two parts.

1. Add H_2S or $(\text{NH}_4)_2\text{S}$. A white precipitate indicates **Zinc**. Confirm by flame-reaction.

2. Add HCl till acid, then $(\text{NH}_4)\text{HO}$ till alkaline. A white precipitate indicates **Aluminium**. Confirm by flame reaction.

F.

Cobalt, Aluminium, Zinc, Manganese, and Chromium.

(till alkaline) + NH_4Cl + $(\text{NH}_4)_2\text{S}$. Warm the mixture gently in a small flask well with H_2O , containing $(\text{NH}_4)_2\text{S}$, and finally once with H_2O alone. Treat dilute HCl , and filter.

FILTRATE.

Cr, Al, Fe, Zn, and Mn.

(Green or violet if Cr be present. Boil down a portion and test for Cr by borax bead. Adopt Method I. if absent, Method II. if present.)

METHOD II. Cr IS PRESENT.

Boil down with a little KClO_3 till it smells of Cl . Add Na_2CO_3 or NaHO till just neutral or slightly acid; allow to become *perfectly* cold. Add excess of BaCO_3 , place in a flask, cork up and shake well, allow to stand till clear. Filter.

RESIDUE.

FILTRATE.

$\text{Fe}_2(\text{HO})_6$, $\text{Cr}_2(\text{HO})_6$, $\text{Al}_2(\text{HO})_6$ (also excess of BaCO_3).

Wash well, boil with pure NaHO , and filter; add HCl to the filtrate, and then $(\text{NH}_4)\text{HO}$ till alkaline. A white precipitate indicates **Aluminium**. Confirm by flame-reaction. Fuse the residue insoluble in NaHO with a mixture of Na_2CO_3 and KNO_3 , extract with water, and filter.

RESIDUE.

FILTRATE.

$\text{Fe}_2(\text{HO})_6$.

Dissolve in HCl , and test with $\text{K}_4\text{Fe}(\text{CN})_6$. A blue precipitate indicates **Iron**.

Cr.

Yellow in colour. Acidify with acetic acid; add lead acetate. A bright yellow precipitate indicates **Chromium**.

Zn, Mn.

Precipitate the Ba present with H_2SO_4 in the hot solution. Boil well, and filter; add NaHO . Precipitate indicates **Manganese**. Confirm by fusing with Na_2CO_3 and KNO_3 on platinum foil. To the filtrate from the $\text{Mn}(\text{HO})_2$, add $(\text{NH}_4)_2\text{S}$. A white precipitate indicates **Zinc**. Confirm by flame-reaction.

Reactions of the Metals of the Barium Group.

85. Metals whose carbonates are insoluble in water, and whose solutions are precipitated on the addition of $(\text{NH}_4)_2\text{CO}_3$: as, however, the carbonates are soluble in acids, the solution, if acid, must be neutralized by addition of $(\text{NH}_4)\text{HO}$.

Barium, Strontium, Calcium.

BARIUM. Ba, c.w. 137.

1. $(\text{NH}_4)_2\text{CO}_3$ produces a white precipitate of BaCO_3 , soluble in acids, and to a slight extent in NH_4Cl .

2. K_2CO_3 or Na_2CO_3 produces also a precipitate of BaCO_3 , insoluble in excess of either reagent.

3. H_2SO_4 or any soluble sulphate produces, even in dilute solutions, a heavy white precipitate of BaSO_4 , insoluble in acids, alkalies, or salts of ammonium.

4. CaSO_4 or SrSO_4 produces an immediate white precipitate of BaSO_4 .

5. H_2SiF_6 produces a white precipitate of BaSiF_6 .

6. $\text{C}_2(\text{NH}_4)_2\text{O}_4$ produces a white precipitate of C_2BaO_4 , soluble in HCl and in HNO_3 .

7. K_2CrO_4 produces a yellow precipitate of BaCrO_4 , insoluble in $\text{C}_2\text{H}_4\text{O}_2$, but soluble in HCl and HNO_3 .

8. Heated in the lamp flame a green coloration is produced, especially on moistening the salt with HCl .

86. STRONTIUM. Sr, c.w. 87.5.

1. $(\text{NH}_4)_2\text{CO}_3$ or K_2CO_3 precipitates white SrCO_3 , soluble in acids, but less soluble in NH_4Cl than BaCO_3 .

2. H_2SO_4 produces a white precipitate of SrSO_4 , which is much less insoluble in H_2O than BaSO_4 , and it therefore precipitates from dilute solutions only on standing or warming. SrSO_4 is slightly soluble in HCl .

3. CaSO_4 produces, after standing some time, a white precipitate of SrSO_4 .

4. H_2SiF_6 does not precipitate strontium solutions.

5. $\text{C}_2(\text{NH}_4)_2\text{O}_4$ produces a white precipitate of C_2SrO_4 , soluble in HCl and in HNO_3 , also to a slight extent in NH_4Cl , but very sparingly in $\text{C}_2\text{H}_4\text{O}_2$.

6. K_2CrO_4 produces, only in concentrated solutions, a yellow precipitate of SrCrO_4 , soluble in $\text{C}_2\text{H}_4\text{O}_2$.

7. Heated in the lamp flame a crimson coloration is produced, especially on moistening the salt with HCl .

87. CALCIUM. Ca , c.w. 40.

1. $(\text{NH}_4)_2\text{CO}_3$ or K_2CO_3 produces a white precipitate of CaCO_3 , which becomes crystalline on heating.

2. H_2SO_4 precipitates from strong solutions of calcium salts CaSO_4 , as a white precipitate, which dissolves in a large excess of water, and also in acids.

3. CaSO_4 produces no precipitate.

4. H_2SiF_6 produces no precipitate.

5. $\text{C}_2(\text{NH}_4)_2\text{O}_4$ produces, even in dilute solutions, a white precipitate of C_2CaO_4 , soluble in HCl or HNO_3 , but insoluble in $\text{C}_2\text{H}_4\text{O}_2$ or in $\text{C}_2\text{H}_4\text{O}_2$.

6. Heated in the lamp flame, a dull red coloration is produced, especially on moistening the salt with HCl . This reaction is imperceptible in presence of Ba or Sr salts.

88.—CALCIUM GROUP (IV.).

TABLE

Separation of Barium,

Heat filtrate from iron group, add to the hot solution NH_4Cl and add CaSO_4 solution. An immediate precipitate indicates **Barium**; solution. (Test another portion with SrSO_4 for Ba.) To another portion of Neutralize filtrate with $(\text{NH}_4)\text{HO}$, and add $\text{C}_2(\text{NH}_4)_2\text{O}_4$. An immediate

TO TEST FOR

I. Ba PRESENT. Ca ABSENT.

Dissolve the carbonate in HCl , and evaporate to dryness. Treat the residue with strong alcohol. Filter.

RESIDUE.

BaCl_2 .

Confirm by flame test. Green coloration indicates **Barium**.

FILTRATE.

Sr .

Confirm by lighting the alcoholic solution. Crimson coloration indicates **Strontium**.

II. Ba ABSENT.

Dissolve as before, and Filter, and RESIDUE.

SrSO_4 .

If small, burn the filter in the reducing gas flame to convert SrSO_4 into SrS : moisten with HCl , and test in the lamp-flame. Crimson coloration indicates **Strontium**.

ANOTHER

Dissolve in HNO_3 , ness. Treat with strong RESIDUE.

$\text{Sr}(\text{NO}_3)_2$.

Confirm as above.

G.

Strontium, and Calcium.

$(\text{NH}_4)_2\text{CO}_3$, and filter. Wash precipitate with hot H_2O , dissolve in HCl , a precipitate after some time indicates **Strontium**, or a dilute Barium the solution in HCl add H_2SO_4 and boil to remove Ba and Sr. Filter. precipitate indicates **Calcium**.

STRONTIUM.

Ca PRESENT.

precipitate with H_2SO_4 . wash well.

FILTRATE.

Ca.

Neutralize the solution with $(\text{NH}_4)\text{HO}$, and test with $\text{C}_2(\text{NH}_4)_2\text{O}_4$. White precipitate indicates **Calcium**.

METHOD.

and evaporate to dry-alcohol. Filter.

FILTRATE.

Ca.

Confirm as above.

III. Ba AND Ca PRESENT.

Add H_2SO_4 to the HCl solution (diluted to prevent precipitation of Calcium), and filter.

RESIDUE.

Ba SO_4 , Sr SO_4 .

Boil in a beaker with a little water, together with a mixture of three parts K_2SO_4 and one part K_2CO_3 . Filter, and treat residue with HNO_3 . The SrSO_4 is dissolved, and the BaSO_4 left undissolved. (Traces of Ca may be found with the Sr.)

FILTRATE.

Ca.

Neutralize the solution with $(\text{NH}_4)\text{HO}$, and test with $\text{C}_2(\text{NH}_4)_2\text{O}_4$. White precipitate indicates **Calcium**.

ANOTHER METHOD.

Dissolve the carbonates in $\text{C}_2\text{H}_4\text{O}_2$, and precipitate the Ba with K_2CrO_4 . Filter. Precipitate the Sr and Ca by $(\text{NH}_4)_2\text{CO}_3$, and proceed as in Method II. (Ba Absent, Ca Present).

Reactions of the Metals of the Potassium Group.

89. Metals whose solutions are unprecipitated by the preceding group reagents, but which have no common precipitant, and are therefore recognized by individual tests.

Magnesium, Potassium, Ammonium, Sodium.

MAGNESIUM. Mg, c.w. 24.

1. Na_2HPO_4 produces, in presence of $(\text{NH}_4)\text{HO}$ and NH_4Cl , a crystalline white precipitate of MgNH_4PO_4 . From dilute solutions the precipitation is slow, but may be hastened by stirring with a glass rod. The precipitate is soluble in dilute mineral acids and in $\text{C}_2\text{H}_4\text{O}_2$, but is almost insoluble in dilute solution of $(\text{NH}_4)\text{HO}$.

2. $(\text{NH}_4)\text{HO}$ in neutral solutions produces a partial precipitation of the hydrate $\text{Mg}(\text{HO})_2$, but gives no precipitate in presence of NH_4Cl , in which the hydrate is readily soluble.

3. H_2SO_4 , H_2SiF_6 , and $\text{C}_2(\text{NH}_4)_2\text{O}_4$ yield no precipitates.

4. Heated on charcoal in the blow-pipe flame, then moistened with CoCl_2 and re-heated, a pink mass is obtained.

90. POTASSIUM. K, c.w. 39.1.

1. PtCl_4 produces a crystalline yellow precipitate of $2\text{KCl} + \text{PtCl}_4$, except in dilute solutions, which are not precipitated. The precipitation is promoted by stirring, or by addition of alcohol.

2 Tartaric acid precipitates white crystalline hydro-

gen potassium tartrate from strong and neutral solutions. The precipitation is promoted by stirring.

3. H_2SiF_6 produces a white gelatinous precipitate of K_2SiF_6 .

4. Heated on platinum wire in the non-luminous flame, a violet coloration is produced, which when viewed through a piece of blue glass appears reddish violet.

91. AMMONIUM. NH_4 , c.w. 18.

1. PtCl_4 produces a crystalline yellow precipitate of $2\text{NH}_4\text{Cl} + \text{PtCl}_4$, except in dilute solutions, which are not precipitated. The precipitate is insoluble in alcohol and ether, and when ignited leaves a residue of spongy platinum.

2. Tartaric acid produces, in strong solutions, a white precipitate of hydrogen ammonium tartrate, similar in appearance to the corresponding potassium salt.

3. Nessler's solution, added to ammonia or its salts, produces a yellow coloration, or, if the ammonia compound be present in large quantity, a brown precipitate.

4. NaHO or KHO solution when warmed with ammonia salts decomposes them, and NH_3 is evolved, which is recognized by its pungent odour, by its turning red litmus paper blue, and by its forming white fumes with a strong solution of any volatile acid, *e.g.* HCl .

5. Heated on platinum foil, all compounds of ammonia volatilize completely.

92. SODIUM. Na , c.w. 23.

The soda salts are almost without exception soluble in water, so that the flame test alone serves to distinguish the salts of this metal.

1. Heated on platinum foil or wire in the non-luminous lamp flame, an intense yellow colour is produced, which, however, is not seen when viewed through blue glass. It is thus possible to distinguish potassium salts when mixed with sodium salts.

TABLE H.

GROUP V.

93 Separation of Magnesium, Potassium, Sodium, and Ammonium.

The filtrate from the Barium Group is concentrated by evaporation, and a portion evaporated on platinum foil. If no residue is left on ignition, Mg, K, and Na are absent.

Detection of NH_4.	Detection of Mg.	Detection of K and Na.	
The original substance or solution is heated with NaOH in a test tube. Presence of Ammonium shown by smell, by the white fumes with HCl , and by its action on red litmus paper.	To a portion of the concentrated cold solution add $(\text{NH}_4)\text{HO}$ and Na_2HPO_4 . White crystalline precipitate denotes Magnesium .	(1.) Mg. being absent.	(2.) Mg. being present.
To detect Na. Evaporate alcoholic solution (which must have a yellow colour, showing that excess of PtCl_4 has been added) nearly to dryness, add a grain or two of sugar, and ignite residue. Exhaust with water, filter, evaporate to dryness; and if a residue be left, test it by flame reaction for Na . Yellow coloration indicates Sodium .		Evaporate another portion of the solution to dryness, ignite residue, dissolve in a small quantity of water, filter if required, and add to the clear liquid PtCl_4 , evaporate nearly to dryness, and add alcohol. Yellow precipitate indicates Potassium .	
		Evaporate the solution to dryness, ignite residue, dissolve in water, and add baryta water until the solution has an alkaline reaction; boil; filter. To filtrate, add $(\text{NH}_4)_2\text{CO}_3$, heat, filter, evaporate to dryness, and test the residue for K and Na . As Sub. (L)	

PART IV.

REACTIONS OF THE ACIDS.

94. *Grouping of the Acids.*

The acids do not admit of being grouped with the same precision as the bases, but they can be approximately classified by means of certain group reagents. They are divided into two great classes, *Inorganic* and *Organic Acids*. These are readily distinguished by the action of heat.

Salts of *Inorganic Acids* when heated to redness are not charred; salts of *Organic Acids* are at once charred, owing to decomposition and consequent separation of carbon.*

95. *Grouping of the Inorganic Acids.*

GROUP I. (SULPHURIC ACID GROUP).

Group reagent, BaCl_2 in presence of HCl .

Sulphuric Acid, Hydrofluosilicic Acid.

The acids of this group are precipitated by BaCl_2 , and the precipitate is not dissolved on addition of HCl .

* With the exception of acetic and formic acids. (See 128 and 129.)

GROUP II. (PHOSPHORIC ACID GROUP).

Group reagent, BaCl_2 .

Phosphoric, Boric, Oxalic, Hydrofluoric, Carbonic, Silicic, Sulphurous, Hyposulphurous, Arsenious, Arsenic, Iodic, and Chromic Acids.

The acids of this group are precipitated in *neutral solutions* by BaCl_2 .

GROUP III. (HYDROCHLORIC ACID GROUP).

Group reagent, AgNO_3 .

Hydrochloric, Hydrobromic, Hydriodic, Hydrocyanic, Hypochlorous, Nitrous, and Hydrosulphuric Acids.

The acids of this group are precipitated by AgNO_3 , and *not* by BaCl_2 .

GROUP IV. (NITRIC ACID GROUP).

Nitric, Chloric, and Perchloric Acids.

These acids are not precipitated by any reagent, as all their salts are soluble in water.

Reactions of the Inorganic Acids belonging to Group I.

96. Acids precipitated by BaCl_2 in presence of HCl .

Sulphuric Acid, Hydrofluosilicic Acid.

SULPHURIC ACID. H_2SO_4 , c.w. 98.

1. BaCl_2 produces a white precipitate of BaSO_4 , insoluble in HCl or HNO_3 . In very dilute solutions the precipitation is not immediate, but on standing the solution becomes clouded, and ultimately the precipitate subsides.

2. $\text{Pb}(\text{NO}_3)_2$ produces a heavy white precipitate of PbSO_4 , soluble in NaHO , and in boiling HCl (on allowing this solution to cool, PbCl_2 crystallizes out).

3. Fused on charcoal with Na_2CO_3 in the reducing flame of the blow-pipe, a sulphide is produced. If the fused mass be moistened with HCl , the odour of H_2S is at once perceptible; or if it be placed on a bright piece of silver and moistened with water, a black stain of Ag_2S is produced. As the latter reaction is very delicate, care must be taken to use Na_2CO_3 perfectly free from Na_2SO_4 , and it must be borne in mind that other sulphur acids give the same reaction when heated with Na_2CO_3 .

97. HYDROFLUO-SILICIC ACID. H_2SiF_6 , c.w. 144.

1. BaCl_2 produces a crystalline precipitate of BaSiF_6 , insoluble in HCl .

2. KCl produces a gelatinous precipitate of K_2SiF_6 .
3. Heated with sulphuric acid in a platinum or leaden crucible covered with a watch-glass, the latter is etched owing to the disengagement of HF.

Reactions of the Acids belonging to Group II.

98. Acids precipitated by $BaCl_2$ in neutral solutions.

Phosphoric, Boric, Oxalic, Hydrofluoric, Carbonic, Silicic, Sulphurous, Hyposulphurous, Arsenious, Arsenic, Iodic, and Chromic Acids.

PHOSPHORIC ACID. H_3PO_4 , c.w. 98. (Ortho-phosphoric Acid.)

1. $BaCl_2$ produces a white precipitate of $BaHPO_4$, readily soluble in HNO_3 or HCl , but with difficulty in NH_4Cl .
2. $MgSO_4$, along with $(NH_4)HO$ and NH_4Cl , produces a white crystalline precipitate of $Mg(NH_4)PO_4 \cdot 6H_2O$, insoluble in $(NH_4)HO$, but soluble in HCl , HNO_3 , and acetic acid. In dilute solutions the precipitation does not take place till after the lapse of some time, but is promoted by stirring and gentle warming.
3. $AgNO_3$ produces a yellow precipitate of Ag_3PO_4 , soluble in HNO_3 , and also in $(NH_4)HO$.
4. Lead acetate produces a white precipitate of $Pb_3(PO_4)_2$, soluble in HNO_3 , but almost insoluble in acetic acid.
5. Fe_2Cl_6 , in presence of excess of sodium acetate,

produces a yellowish precipitate of FePO_4 , soluble in HCl , and in excess of Fe_2Cl_6 , which ought therefore to be added drop by drop.*

6. Ammonium molybdate produces in solutions made acid with HNO_3 a yellow coloration and ultimately a precipitate. The reaction is hastened by warming the mixture.

The following acids of phosphorus are distinguished from each other and from ortho-phosphoric acid by the following reactions :—

Pyrophosphoric Acid. $\text{H}_4\text{P}_2\text{O}_7$, c.w. 178.

1. AgNO_3 produces a white precipitate of $\text{Ag}_4\text{P}_2\text{O}_7$, soluble in HNO_3 , and in $(\text{NH}_4)\text{HO}$.

2. Albumen gives no precipitate.

Metaphosphoric Acid. HPO_3 , c.w. 80.

1. AgNO_3 produces a white gelatinous precipitate of AgPO_3 .

2. Albumen produces a flocculent white precipitate when added to metaphosphoric acid, and the same precipitate when added to a solution of a metaphosphate acidified with acetic acid.

3. $\text{MgSO}_4 + \text{NH}_4\text{Cl} + (\text{NH}_4)\text{HO}$ produces no precipitate.

* If the test be applied to an acid solution of a phosphate insoluble in water (e.g. $\text{Ca}_3(\text{PO}_4)_2$ in HCl), the free acid is first nearly neutralized with $(\text{NH}_4)\text{HO}$, sodium acetate next added, and then Fe_2Cl_6 ; after this the mixture is boiled. The precipitate, which is of a reddish brown colour, contains all the iron and phosphoric acid; the filtrate contains the base. The phosphoric acid can easily be separated from the iron, and obtained as a soluble ammonium salt by treating the ferric phosphate with $(\text{NH}_4)_2\text{S}$.

99. BORIC ACID. $B(HO)_3$, c.w. 62.

1. $BaCl_2$ produces a white precipitate of $Ba(BO_2)_2$, soluble in acids.

2. $AgNO_3$ produces in strong solutions a yellowish white precipitate. In dilute solutions Ag_2O is precipitated.

3. H_2SO_4 or HCl , added to hot concentrated solutions of alkaline borates, produces on cooling a crystalline precipitate of $B(HO)_3$.

4. If alcohol containing free boric acid be kindled, it burns with a green flame, best seen on stirring the mixture. Borates may be examined in this way by first adding strong H_2SO_4 , to liberate the $B(HO)_3$.

5. If the solution of a borate be made distinctly acid with HCl , and turmeric paper dipped into it, the latter on gentle warming acquires a brown tint, which is turned blue by caustic soda.

100. OXALIC ACID. $C_2H_2O_4$, c.w. 90.

1. $BaCl_2$ produces in neutral solutions a white precipitate of C_2O_4Ba , soluble in HNO_3 , in HCl , and in $C_2H_3O_4$.

2. $AgNO_3$ produces a white precipitate of $C_2O_4Ag_2$, soluble in HNO_3 , and in $(NH_4)HO$.

3. $CaCl_2$ produces even in dilute solutions a white precipitate of C_2O_4Ca , soluble in HNO_3 , and in HCl , but nearly insoluble in $(NH_4)HO$, and in acetic acid. On igniting C_2O_4Ca , a white residue of $CaCO_3$ is left, which effervesces on the addition of an acid.

4. Heated with strong H_2SO_4 , effervescence takes

place from the escape of a mixture of CO and CO₂, and the former may be kindled at the mouth of the test tube, and will burn with a pale blue flame. *No blackening* of the mixture occurs as in the case of organic acids, which yield CO on heating with H₂SO₄.

101. HYDROFLUORIC ACID. HF, c.w. 20.

1. BaCl₂ produces a white precipitate of BaF₂, soluble in HCl, and sparingly in NH₄Cl.

2. CaCl₂ produces a gelatinous and almost transparent precipitate of CaF₂, difficult to discern in the fluid, but made more apparent on addition of (NH₄)HO. The precipitate is very difficultly soluble in HCl, even on boiling, and is nearly insoluble in acetic acid.

3. Heated with H₂SO₄, all fluorides are decomposed with evolution of HF, which is recognized by its power of etching glass. (See 47.)

This is best done by placing the fluoride in a platinum crucible, or small leaden cup, along with strong H₂SO₄, and covering the mouth with a waxed watch-glass, convex side downwards, on which a few scratches have been made with a needle. The concave side of the watch-glass is filled with water to prevent the wax on the other side from melting, and the crucible or cup is then gently heated. On removing the glass and melting off the wax by gentle warming, the glass will be found etched at the unprotected parts.*

* If the fluoride contain much silica, SiF₄ is evolved instead of HF, and is detected by heating the substance with H₂SO₄ in a test tube, and leading the evolved gas into water. Silica will separate out in flocculent tufts, and H₂SiF₆ will be found in solution.

4. Heated with a mixture of borax and HKSO_4 , on a loop of platinum wire in the non-luminous gas flame, BF_3 is produced, which momentarily colours the flame green.

102. CARBONIC ACID. H_2CO_3 or $\text{H}_2\text{O} + \text{CO}_2$.

1. BaCl_2 produces in neutral solutions a white precipitate of BaCO_3 , soluble in acids with effervescence.

2. Treated with dilute HCl , all carbonates at once evolve CO_2 with effervescence, and if this gas be conducted into lime-water it produces a turbidity from formation of CaCO_3 . (The experiment may be conveniently performed by placing the carbonate and dilute acid in one test tube and the lime-water in another. As soon as the CO_2 has collected, it may be decanted into the lime-water tube—care being taken to prevent any liquid from being decanted with it—and on shaking the latter the lime-water will become turbid.)

103. SILICIC ACID. $\text{Si}(\text{HO})_4$, c.w. 96.

1. BaCl_2 produces a white precipitate of SiBa_2O_4 , which is decomposed on addition of HCl , and $\text{Si}(\text{HO})_4$ separates out as a gelatinous precipitate.

2. HCl , added drop by drop to a strong solution of a silicate, produces a gelatinous precipitate of $\text{Si}(\text{HO})_4$, but if added to a dilute solution or in large excess, no precipitate is obtained until the mixture has been evaporated to dryness and ignited, when SiO_2 separates out, and this is not re-dissolved on addition of HCl .

3. Fused with Na_2CO_3 in a loop of platinum wire in

the non-luminous gas flame, effervescence occurs from the disengagement of CO_2 , and the bead is transparent on cooling, unless the Na_2CO_3 be in excess.

4. Fused with microcosmic salt on a loop of platinum wire in the non-luminous gas flame, solution does not take place, but the silica floats about on the bead undissolved.

104. The remaining six acids of this group are precipitated or decomposed by one or other of the group reagents for *bases*, and are therefore precipitated in the course of examination, for bases, or expelled on the addition of HCl . The action of the *base* group-reagents is as follows :—

Ag Group.	{	H_2SO_3 decomposed by HCl , with evolution of SO_2 .
	{	$\text{H}_2\text{S}_2\text{O}_3$ decomposed by HCl , with evolution of SO_2 and separation of S.
As Group.	{	H_3AsO_3 precipitated by H_2S as As_2S_3 (yellow).
	{	H_3AsO_4 " " " "
	{	HIO_3 decomposed by H_2S , with formation of an iodide and separation of S.
Fe Group.	{	H_2CrO_4 precipitated by $(\text{NH}_4)_2\text{S}$ as $\text{Cr}_2(\text{HO})_6$.

The following are additional tests for these acids :—

105. SULPHUROUS ACID. H_2SO_3 , c.w. 82.

1. BaCl_2 produces a white precipitate of BaSO_3 , soluble in HCl . This solution, on addition of chlorine

water, yields a white precipitate of BaSO_4 , the sulphite being oxidized to sulphate.

2. AgNO_3 produces a white precipitate of Ag_2SO_3 , which darkens on heating, from precipitation of Ag.

3. Added to a mixture of zinc and HCl , H_2S is produced and recognized by its smell and blackening action on paper moistened with solution of a lead salt.

4. H_2S decomposes free H_2SO_3 with separation of sulphur.

106. HYPOSULPHUROUS ACID. $\text{H}_2\text{S}_2\text{O}_3$, c.w. 114.

1. BaCl_2 produces a white precipitate of BaS_2O_3 , soluble in HCl , with formation of sulphur as a yellow precipitate.

2. HCl or H_2SO_4 produces no immediate precipitate, but on standing a short time sulphur is precipitated (yellow), and simultaneously SO_2 is evolved.

3. AgNO_3 produces a white precipitate of $\text{Ag}_2\text{S}_2\text{O}_3$, which rapidly darkens in colour and becomes ultimately black from formation of Ag_2S . These changes are hastened by heat.

4. Fe_2Cl_6 produces a reddish coloration, but on heating it is decolorized, the ferric being reduced to ferrous chloride.

107. ARSENIOUS ACID. H_3AsO_3 , c.w 126.

1. AgNO_3 produces in *neutral* solutions a yellow precipitate of Ag_3AsO_3 , soluble in $(\text{NH}_4)\text{HO}$. If no precipitate appear at first owing to the solution not

being neutral, add a few drops of a *very* dilute solution of $(\text{NH}_4)\text{HO}$ until it appears. (See 75, 2.)

2. $\text{MgSO}_4 + \text{NH}_4\text{Cl} + (\text{NH}_4)\text{HO}$ produce no precipitate.

(See also reactions for Arsenic, 75.)

108. ARSENIC ACID. H_3AsO_4 , c.w. 142.

1. AgNO_3 produces in neutral solutions a light brown precipitate of Ag_3AsO_4 . If necessary, add very dilute ammonia, as in the preceding case.

2. $\text{MgSO}_4 + \text{NH}_4\text{Cl} + (\text{NH}_4)\text{HO}$ produce a white precipitate of $\text{MgNH}_4\text{AsO}_4$.

(See also reactions for Arsenic, 75.)

109. IODIC ACID. HIO_3 , c.w. 176.

1. BaCl_2 produces a white precipitate of $\text{Ba}(\text{IO}_3)_2$, soluble in HNO_3 .

2. AgNO_3 produces a white crystalline precipitate of AgIO_3 , readily soluble in $(\text{NH}_4)\text{HO}$, but sparingly soluble in HNO_3 .

3. SO_2 produces at first a precipitate of I , which is converted into HI on addition of excess of the re-agent.

4. On heating, iodates are decomposed, oxygen being evolved, and in some cases iodine is also given off in violet vapours.

110. CHROMIC ACID. H_2CrO_4 , c.w. 118.2.

1. BaCl_2 produces a yellow precipitate of BaCrO_4 , soluble in HCl and HNO_3 , but insoluble in acetic acid.

2. H_2S in presence of HCl reduces the solution to Cr_2Cl_6 (green), with separation of S . In neutral solutions, $\text{Cr}_2(\text{HO})_6$ is precipitated along with S .

3. SO_2 reduces solutions of chromates to the chromic salt, the colour of which is green. Chromates are likewise reduced by zinc and a dilute acid, by oxalic acid and dilute sulphuric acid, by strong H_2SO_4 , by strong HCl , and by boiling the solution acidified with HCl or H_2SO_4 along with alcohol.

4. AgNO_3 produces a dark red precipitate of Ag_2CrO_4 , soluble in HNO_3 and in $(\text{NH}_4)\text{HO}$.

5. Lead acetate produces a bright yellow precipitate of PbCrO_4 , soluble in NaHO , but soluble with difficulty in dilute HNO_3 .

(See also reactions for Chromium, 83.)

Reactions of the Acids belonging to Group III.

111. Acids precipitated by AgNO_3 , and not by BaCl_2 .

Hydrochloric, Hydrobromic, Hydriodic, Hydrocyanic, Hypochlorous, Nitrous, and Hydrosulphuric Acids.

HYDROCHLORIC ACID. HCl , c.w. 36.5.

1. AgNO_3 produces a white curdy precipitate of AgCl , which becomes violet on exposure to light. The precipitate is insoluble in HNO_3 , but soluble in $(\text{NH}_4)\text{HO}$, in KCN , in $\text{Na}_2\text{S}_2\text{O}_3$, and also to some extent in NaCl .

TESTS FOR HYDROBROMIC ACID. 109

2. Heated with H_2SO_4 and MnO_2 , chlorides yield chlorine gas, recognized by its smell, bleaching action, and green colour.

3. *Dry* chlorides, when heated in a retort with H_2SO_4 and $\text{K}_2\text{Cr}_2\text{O}_7$, yield CrO_2Cl_2 (chromium oxy-chloride), which distils over into the receiver as a dark red liquid, decomposed by addition of water or $(\text{NH}_4)\text{HO}$, yielding a yellow solution, which, on addition of a lead salt, gives a yellow precipitate of PbCrO_4 .

112. HYDROBROMIC ACID. HBr , c.w. 81.

1. AgNO_3 produces a pale yellow precipitate of AgBr , insoluble in dilute HNO_3 , soluble in strong $(\text{NH}_4)\text{HO}$, and readily in KCN and $\text{Na}_2\text{S}_2\text{O}_3$.

2. Chlorine passed through a solution of a bromide decomposes it with liberation of Br , which dissolves in the liquid and colours it yellow. If this solution be shaken up with ether, the bromine is dissolved by it, and the yellow ethereal solution floats above the liquid which becomes colourless. If the ethereal solution be then separated from the liquid, and NaHO be added, the yellow colour disappears, and NaBr and NaBrO_3 are produced. On evaporation and ignition, oxygen is evolved and NaBr alone remains, which may be tested as in 3.

3. Heated with H_2SO_4 and MnO_2 , bromides yield red vapours of Br , recognized by its powerful odour.

4. Heated in a retort with $\text{K}_2\text{Cr}_2\text{O}_7$ and H_2SO_4 , dry bromides yield dark red vapours, which condense in the receiver to a liquid of the same colour, which

consists of pure bromine, and is decolorized on adding excess of $(\text{NH}_4)\text{HO}$. (Compare Hydrochloric Acid test, 111, 3.)

113. HYDRIODIC ACID. HI , c.w. 128.

1. AgNO_3 produces a pale yellow precipitate of AgI , insoluble in dilute HNO_3 , and very difficultly soluble in $(\text{NH}_4)\text{HO}$, but readily in KCN and $\text{Na}_2\text{S}_2\text{O}_3$.

2. Cuprous sulphate * produces a dirty-white precipitate of Cu_2I_2 , which separates most completely if the solution be made slightly alkaline with Na_2CO_3 . The reagent produces no precipitate in solutions of chlorides or bromides.

3. KNO_2 produces no reaction in solutions of iodides until a few drops of HCl or H_2SO_4 are added, when iodine is at once liberated and colours the solution yellow. If a little starch solution be now added, a deep blue coloration results from the formation of starch iodide. On warming the blue liquid the colour disappears, but reappears on cooling. The production of blue starch iodide is the most characteristic test for iodine.

4. Chlorine water (or the gas) liberates iodine from iodides, but *excess* of Cl causes the formation of ICl_3 , which is colourless, and gives no blue coloration with starch solution. If therefore chlorine water be added drop by drop to a solution of an iodide mixed with starch solution, a blue coloration is produced,

* Prepared by dissolving a mixture of two parts CuSO_4 and five parts FeSO_4 in water, or by the action of SO_2 on CuSO_4 .

TESTS FOR HYDROCYANIC ACID. 111

which disappears on further addition of the reagent.

5. Free iodine (liberated by either of the above methods) is dissolved by CS_2 , forming a violet-coloured solution. If then, a solution of iodine be shaken up with CS_2 , the latter acquires a violet colour. Chloroform may be substituted for CS_2 .

6. Heated with MnO_2 and dilute H_2SO_4 , violet vapours of iodine are obtained, which colour paper moistened with starch, blue.

114. HYDROCYANIC ACID. HCN , c.w. 27.

1. AgNO_3 produces a white precipitate of AgCN , insoluble in HNO_3 , with difficulty in $(\text{NH}_4)\text{HO}$, but readily in KCN and $\text{Na}_2\text{S}_2\text{O}_3$. AgCN is decomposed on ignition, and metallic Ag remains ; this serves to distinguish it from AgCl , which is not decomposed on ignition.

2. If a solution of FeSO_4 , which has become oxidized by exposure to the air, be added to the solution of a cyanide made alkaline with NaHO , a bluish green precipitate is formed, which is a mixture of Prussian blue with the hydrated oxides of iron. On adding HCl , these last are dissolved, and the blue precipitate remains.

3. HCl decomposes nearly all cyanides with evolution of HCN , recognized by its odour, resembling bitter almonds. If a cyanide be thus decomposed in a small porcelain basin, covered by a similar basin on which a drop of $(\text{NH}_4)_2\text{S}_2$ (yellow) adheres, the

latter is converted into $(\text{NH}_4)\text{CNS}$, which gives a blood-red coloration on addition of Fe_2Cl_6 and HCl .

NOTE.— $\text{Hg}(\text{CN})_2$ cannot be detected by the above methods. The dry substance is detected by igniting in a small tube, when cyanogen gas is evolved, or the solution is decomposed by H_2S and filtered from the HgS ; the filtrate contains HCN .

115. HYPOCHLOROUS ACID. HClO , c.w. 52.5.

1. AgNO_3 produces a white precipitate of AgCl .
2. $\text{Pb}(\text{NO}_3)_2$ produces a white precipitate, which changes in colour to red, and ultimately to brown from formation of PbO_2 .
3. MnCl_2 produces a dark brown precipitate of $\text{MnO}(\text{HO})_2$.
4. Indigo and litmus solution are decolorized, especially on addition of an acid.
5. Dilute acids decompose hypochlorites with evolution of Cl . HNO_3 evolves HClO from hypochlorites.

116. NITROUS ACID. HNO_2 , c.w. 47.

1. AgNO_3 produces a white precipitate of AgNO_2 , soluble in a large excess of water.
 2. H_2S , in presence of acid, produces a precipitate of S , and $(\text{NH}_4)\text{NO}_3$ remains in solution.
 3. FeSO_4 , in presence of an acid, produces a black coloration from solution of NO in the FeSO_4 .
- (See also 113, test 3.)

117. HYDROSULPHURIC ACID (Sulphuretted Hydrogen). H_2S , c.w. 34.

1. AgNO_3 produces a black precipitate of Ag_2S , insoluble in dilute acids.

2. Lead acetate, even when highly dilute, produces a black precipitate of PbS .

3. Sodium nitro-prusside, in presence of NaHO , produces a reddish violet coloration, even in very dilute solutions. The colour disappears in a short time.

4. HCl or H_2SO_4 decomposes most sulphides with evolution of H_2S , recognized by its disagreeable odour and by its blackening paper moistened with solution of lead.

Reactions of the Acids belonging to Group IV.

118. Acids not precipitated by any reagent.

Nitric, Chloric, and Perchloric Acids.

NITRIC ACID. HNO_3 , c.w. 63.

1. Nitrates when heated evolve oxygen, and in some cases nitrous vapours also. On fusing a nitrate and adding a fragment of charcoal, vivid deflagration occurs.

(For the reactions of Nitric Acid, see 22.)

119. CHLORIC ACID. HClO_3 , c.w. 84.5.

1. H_2SO_4 decomposes chlorates with evolution of Cl_2O_4 , a greenish yellow gas, having a powerful odour.

If heated, violent explosions occur : the mixture ought therefore to be kept cold, and only *very* small quantities should be used.

2. When chlorates are heated, oxygen is evolved and a metallic chloride remains, which may be dissolved in water and precipitated, as AgCl , by AgNO_3 . (See 5.)

3. Indigo solution, if added to the solution of a chlorate, is decolorized on addition of H_2SO_4 , and solution of Na_2SO_3 .

4. HCl decomposes chlorates with evolution of Cl and Cl_2O_4 , a mixture called *euchlorine*.

5. Heated with charcoal, chlorates deflagrate violently.

PERCHLORIC ACID. HClO_4 , c.w. 100'5.

1. H_2SO_4 does not act upon perchlorates in the cold, and on heating white fumes of HClO_4 are given off but no explosions occur. (Compare 119, 1.)

2. KCl produces in strong solutions a white precipitate of KClO_4 .

3. Indigo solution is not decolorized when added to perchlorates mixed with HCl .

4. Dry perchlorates evolve oxygen on heating.

5. Anhydrous perchloric acid is a colourless fuming liquid, which explodes with great violence when dropped on wood charcoal. (*Roscoe*.)

TABLE J.

120. Detection of Inorganic Acids in Mixtures.

[The following acids are found in the examination for bases, which ought always to *precede* the examination for acids:— H_2SO_3 , H_2CO_3 , H_2S , $Si(HO)_4$, H_2CrO_4 , H_3AsO_3 , and H_3AsO_4 .]

(a) Acids in Soluble Bodies.

1. Neutralize a portion of the solution with $(NH_4)HO$ and add $BaCl_2$ (or $Ba(NO_3)_2$ if Ag , Hg_2 , or Pb be present): precipitate indicates H_2SO_4 , H_3PO_4 , H_3AsO_3 , H_3AsO_4 , $Si(HO)_4$, H_2CrO_4 , $\overline{Ox}$, $\overline{Ci}$, $\overline{T}$,* and large quantities of $B(HO)_3$ and HF .

To precipitate, add water and then HCl : if a precipitate remain, H_2SO_4 was present.

2. To another portion of the neutralized solution add $AgNO_3$: a precipitate indicates one or more of the following acids:—

(a) HCl , HBr , HI , HCN , $H_4Fe(CN)_6$, $H_3Fe(CN)_6$, H_2S .

(b) H_3PO_4 , H_3AsO_4 , H_3AsO_3 , H_2CrO_4 , $Si(HO)_4$, $B(HO)_3$, $\overline{Ox}$, $\overline{T}$, and $\overline{Ci}$. To the precipitate add cold dilute HNO_3 . Acids under (a) are insoluble, those under (b) soluble.

* $\overline{Ox}$, $\overline{Ci}$, and $\overline{T}$ are contractions for oxalic, citric, and tartaric acids. (For the further separation of these organic acids, see Table K.)

DETECTION OF ACIDS UNDER (a).

To a portion of the solution add starch paste and one drop of a solution of N_2O_3 in H_2SO_4 . Blue coloration indicates **HI**. Add now chlorine water till the blue colour disappears, and shake with chloroform. If this becomes reddish brown in colour, the presence of **HBr** is indicated. **HCl** is detected in the presence of the others by boiling down the solution to dryness and distilling the residue with $\text{K}_2\text{Cr}_2\text{O}_7$ and H_2SO_4 . (See 111, 3.)

DETECTION OF ACIDS UNDER (b).

Test separately for each acid by the methods already given.

SEPARATION OF H_3AsO_3 , H_3AsO_4 , AND H_3PO_4 .

Acidify solution with HCl , add Na_2SO_3 , and heat until no smell of SO_2 is given off. Pass H_2S through the hot solution, filter, and test for H_3PO_4 with ammonium molybdate: yellow precipitate indicates **H_3PO_4** . Precipitate another portion with magnesia mixture, and test both precipitate and filtrate for arsenic.

TEST FOR THE REMAINING ACIDS BY THE FOLLOWING REACTIONS GIVEN UNDER EACH ACID.

For HCN by test 3, 114.

For $\text{H}_4\text{Fe}(\text{CN})_6$ by tests 3 and 4, 126.

For $\text{H}_3\text{Fe}(\text{CN})_6$, by tests 2 and 3, 127.

For H_2S , by test 4, 117.

*For HNO_3 , by tests b and c, 22.

For HClO_3 , by tests 1 and 2, 119.

For Ox and HF , by CaCl_2 + acetic acid. Confirm Ox by test 4, 100, and HF by test 3, 101.

For $\text{B}(\text{HO})_3$, by tests 4 and 5, 99.

For $\text{Si}(\text{HO})_4$, by tests 2 and 4, 103.

For H_2CrO_4 , by tests 4 and 5, 110.

For H_2SO_3 by test 3, 105, and smell of SO_2 on adding HCl .

For CO_2 by test 2, 102.

(β) Acids in Insoluble Bodies.

Some idea of the nature of the compound is generally obtained by the preliminary examination (Tables A and B). If not dissolved by the

* If HI be present, it must first be removed by addition of FeSO_4 + CuSO_4 . (See 113, 2.)

ordinary reagents, the substance must be fused with about four times its weight of a mixture of Na_2CO_3 and K_2CO_3 . When cold, extract the fused mass with water, and filter if necessary. The filtrate contains the acid, and is neutralized with HCl or HNO_3 , and examined by the methods given under (a).

The sulphates of barium, strontium, and calcium are decomposed by boiling with a *concentrated* solution of Na_2CO_3 . Filter, and examine the filtrate for the acid.

Nitric acid and aqua regia oxidize sulphides to sulphates: hence the solution of a sulphide in these acids always contains H_2SO_4 . In such cases a separate portion of the substance must be examined for H_2SO_4 by boiling with HCl , diluting with water, and then testing with BaCl_2 .

121. GROUPING OF THE ORGANIC ACIDS.**GROUP I. (TARTARIC ACID GROUP).**

Group reagent, CaCl_2 .

Tartaric Acid and Citric Acid (Oxalic Acid, see 100).

Acids which are precipitated by CaCl_2 in the cold or on boiling.

GROUP II. (BENZOIC ACID GROUP).

Group reagent, Fe_2Cl_6 .

Benzole and Succinic Acids.

Acids which are not precipitated by CaCl_2 , but which give precipitates with Fe_2Cl_6 in neutral solutions.

GROUP III.

Group reagent, AgNO_3 .

Ferro-cyanic, Ferri-cyanic, Acetic and Formic Acids.

Acids precipitated by AgNO_3 in neutral solutions, and not by CaCl_2 , or Fe_2Cl_6 . Acetates and Formates are only precipitated in concentrated solutions.

**Reactions of the Organic Acids belonging to Group I.
(Tartaric Acid Group.)**

Acids precipitated by CaCl_2 in the cold or on boiling.

Tartaric and Citric Acids.

122. TARTARIC ACID. $\text{C}_4\text{H}_6\text{O}_6$.

1. CaCl_2 in neutral solutions produces a white precipitate of $\text{C}_4\text{H}_4\text{CaO}_6$, soluble in acids, and in ammoniacal salts. The precipitate is soluble in KHO , but is re-precipitated when the solution is boiled, and on cooling is re-dissolved.

2. KCl produces in solutions containing $\bar{\text{T}}$ in excess a white crystalline precipitate of $\text{C}_4\text{H}_5\text{KO}_6$, soluble in mineral acids and alkalies, insoluble in acetic acid. The precipitation is promoted by stirring, or by addition of alcohol.

3. Lime-water produces in neutral solutions a white precipitate $\text{C}_4\text{H}_4\text{CaO}_6$ (flocculent at first, afterwards crystalline), soluble in tartaric acid and NH_4Cl , but re-precipitated in crystals from these solutions after standing some time.

4. AgNO_3 in neutral solutions produces a white precipitate of $\text{C}_4\text{H}_4\text{Ag}_2\text{O}_6$, soluble in HNO_3 and in $(\text{NH}_4)\text{HO}$. If the solution in $(\text{NH}_4)\text{HO}$ be warmed in a test tube kept at a temperature of about 66°C . for some time, the glass becomes coated with a mirror of silver.

5. Heated with H_2SO_4 , the mixture darkens rapidly

from separation of carbon, and SO_2 , CO , and CO_2 are evolved.

6. Heated to redness, the substance darkens in colour and gives off the characteristic odour of burnt sugar.

123. CITRIC ACID. $\text{C}_6\text{H}_8\text{O}_7$.

1. CaCl_2 produces no precipitate in neutral solutions in the cold, but on boiling, $\text{Ca}_3(\text{C}_6\text{H}_5\text{O}_7)_2$ is precipitated, and is not soluble in KHO , but soluble in $(\text{NH}_4)\text{HO}$.

2. Lime-water produces no precipitate in cold neutral solutions, but on boiling, $\text{Ca}_3(\text{C}_6\text{H}_5\text{O}_7)_2$ is precipitated.

3. AgNO_3 produces in neutral solutions a white flocculent precipitate of $\text{C}_6\text{H}_5\text{Ag}_3\text{O}_7$, soluble in $(\text{NH}_4)\text{HO}$: this solution does not blacken on boiling.

4. Heated with H_2SO_4 , CO_2 and CO are evolved without any darkening in colour; on continued heating, however, the mixture darkens, and SO_2 is evolved.

5. Heated to redness, irritating fumes are given off, readily distinguished from those given off by heating the preceding acid.

**Reactions of the Acids belonging to Group II.
(Benzoic Acid Group.)**

124. Acids precipitated by Fe_2Cl_6 and not by CaCl_2 .

Benzoic and Succinic Acids.

BENZOIC ACID. $\text{C}_7\text{H}_6\text{O}_2$.

1. Fe_2Cl_6 produces, in neutral solutions, a buff-coloured precipitate of ferric benzoate, decomposed by

(NH_4)HO with formation of a more basic benzoate and ammonium benzoate. Ferric benzoate is soluble in HCl with liberation of benzoic acid.

2. Heated with H_2SO_4 , benzoic acid does not blacken.

3. Heated in an open tube, the acid sublimes in needle-shaped crystals, and an irritating vapour is given off. When kindled, the crystals burn with a smoky flame.

125. SUCCINIC ACID. $\text{C}_4\text{H}_6\text{O}_4$.

1. Fe_2Cl_6 produces, in neutral solutions, a reddish brown bulky precipitate of ferric succinate, soluble in mineral acids, and decomposed by (NH_4)HO in a similar manner to ferric benzoate.

2. Lead acetate produces a white precipitate of lead succinate, soluble in excess of the reagent and in HNO_3 .

3. BaCl_2 , in presence of (NH_4)HO and alcohol, produces a white precipitate of barium succinate; this reaction serves to distinguish this acid from benzoic, which does not give a similar precipitate.

4. Heated in an open tube, the acid sublimes in fine needles; and when kindled, the crystals burn with a bluish but not smoky flame.

Reactions of the Acids belonging to Group III.

126. Acids precipitated by AgNO_3 , in strong neutral solutions.

Ferro-cyanic, Ferri-cyanic, Acetic, and Formic Acids.

FERRO-CYANIC ACID. $\text{H}_4\text{Fe}(\text{CN})_6$.

1. AgNO_3 produces a white precipitate of $\text{Ag}_4\text{Fe}(\text{CN})_6$, insoluble in dilute HNO_3 and in $(\text{NH}_4)\text{HO}$, but soluble in KCN .

2. CuSO_4 produces a reddish brown precipitate of $\text{Cu}_2\text{Fe}(\text{CN})_6$.

3. Fe_2Cl_6 produces a deep blue precipitate of Prussian blue, insoluble in dilute mineral acids, soluble in oxalic acid, and decomposed by NaHO with separation of $\text{Fe}_2(\text{HO})_6$.

4. FeSO_4 gives a light blue precipitate, which rapidly darkens in colour by oxidation.

127. FERRI-CYANIC ACID. $\text{H}_3\text{Fe}(\text{CN})_6$.

1. AgNO_3 produces an orange-coloured precipitate of $\text{Ag}_3\text{Fe}(\text{CN})_6$, insoluble in dilute HNO_3 , soluble in $(\text{NH}_4)\text{HO}$ and KCN .

2. FeSO_4 produces a blue precipitate of $\text{Fe}_3\text{Fe}_2(\text{CN})_{12}$ (Turnbull's blue), insoluble in acids, but decomposed by alkalies.

3. Fe_2Cl_6 produces no precipitate, but alters the colour to a greenish brown.

128. ACETIC ACID. $\text{C}_2\text{H}_4\text{O}_2$.

1. AgNO_3 produces, in neutral solutions, a white crystalline precipitate of $\text{C}_2\text{H}_3\text{AgO}_2$, soluble in $(\text{NH}_4)\text{HO}$ and in hot water.

2. Fe_2Cl_6 in neutral solutions, produces a deep red coloration. On boiling, all the iron separates as a light brown precipitate of basic acetate, and the fluid becomes colourless.

3. A strong solution heated with H_2SO_4 and alcohol yields acetic ether, recognized by its characteristic and pleasant odour.

129. FORMIC ACID. CH_2O_2 .

1. AgNO_3 produces, in neutral *concentrated* solutions, a white precipitate of CHAgO_2 , which rapidly darkens, especially on heating, owing to separation of Ag.

2. Fe_2Cl_6 produces a similar reaction with formates as with acetates.

3. $\text{Hg}_2(\text{NO}_3)_2$ produces a white precipitate of the formate of mercury, which, however, soon becomes grey from separation of Hg.

4. Heated with H_2SO_4 , CO is evolved, and, if lighted, burns with a blue flame.

130. *Higher fatty acid.*

STEARIC ACID. $\text{C}_{18}\text{H}_{36}\text{O}_2$.

1. Heated with alkalis a soap is formed. Thus, with NaHO sodium stearate is formed, which dissolves in warm water and the glycerine separates. Soaps are decomposed by acids, which unite with the base, and the fat separates and may be dissolved in alcohol. From this solution the fat crystallizes in needles.

TESTS FOR ORGANIC ALKALOIDS AND CERTAIN OTHER ORGANIC BODIES.

131. MORPHINE. $C_{17}H_{19}NO_3$ (Opium).*

1. KHO and $(NH_4)HO$ precipitate morphia from its salts, readily soluble in excess of KHO, less readily in excess of $(NH_4)HO$.

2. Concentrated HNO_3 , added to powdered morphia or its salts, produces an orange red coloration, changing afterwards to yellow. The reaction is best seen on a porcelain crucible lid. Addition of $SnCl_2$ or of $Na_2S_2O_3$ destroys the colour.

3. A neutral solution of Fe_2Cl_6 produces, when added to morphia (either in the dry state or in solution), a deep blue colour.

4. HIO_3 , when added either to free or combined morphia, is decomposed with liberation of I, which colours the liquid brown. Starch paper added to the solution becomes blue. Addition of $(NH_4)HO$ deepens the brown colour.

5. H_2SO_4 produces no coloration with morphia or its salts, but on adding a crystal of $K_2Cr_2O_7$ a bright green colour is produced.

132. MECONIC ACID, $C_7H_4O_7$ (Opium).

1. Fe_2Cl_6 produces a deep red coloration, which does not alter on boiling (like ferric acetate), nor on treatment with $HgCl_2$ (like iron sulphocyanide).

* These names refer to the substances from which the alkaloids, &c. are derived.

2. Lead acetate produces a white precipitate of lead meconate, insoluble in acetic acid.

OPIUM SOLUTIONS :—

Opium contains both morphia and meconic acid ; hence, in examining solutions of opium, the reactions of both these substances are obtained. The reaction of Fe_2Cl_6 with meconic acid is highly characteristic, and as meconic acid only occurs in opium, its detection in solutions of opium serves as an indirect indication of the presence of morphia. The two substances are separated by precipitating with lead acetate in presence of acetic acid, and filtering from the lead meconate obtained. The filtrate contains acetate of morphia. If the lead meconate be washed thoroughly and then suspended in water and H_2S passed through, PbS is precipitated, and meconic acid remains in solution and may be obtained in crystals by evaporation.

133. STRYCHNINE. $\text{C}_{21}\text{H}_{22}\text{N}_2\text{O}_2$ (Strychnos nuxvomica and St. Ignatius' bean).

1. Strong pure H_2SO_4 dissolves strychnine without any discoloration of the solution, even when heated to 100°C . This solution produces certain characteristic colours, with the following reagents :—

(a) PbO_2 , blue coloration, changing to violet, then red, and finally yellow.

(b) $\text{K}_2\text{Cr}_2\text{O}_7$, blue coloration, changing soon to yellowish red.

(c) $\text{K}_4\text{Fe}(\text{CN})_6$, violet coloration, changing less quickly.

(d) MnO_2 , violet coloration changing to dark red.

2. Strong HNO_3 dissolves strychnine without discoloration unless heated, when the solution becomes yellow.

3. The taste of strychnine is intensely bitter, and is perceptible even in very dilute solutions.

4. Strychnine, when taken in poisonous doses, produces tetanic convulsions. A most characteristic test, founded on this property, consists in injecting a trace of strychnine under the skin of a young frog, which is soon seized with tetanic convulsions, the body becomes rigid and arched, and the animal soon dies.

134. BRUCINE. $\text{C}_{23}\text{H}_{28}\text{N}_2\text{O}_4 + 4 \text{H}_2\text{O}$ (Strychnos nux vomica and St. Ignatius' bean).

1. HNO_3 , when added to brucine, dissolves it, and produces an intense red coloration, which becomes yellow on heating. If SnCl_2 , $\text{Na}_2\text{S}_2\text{O}_3$ or $(\text{NH}_4)_2\text{S}$ be then added, the colour changes to violet. (Compare corresponding reaction with Morphia, 131, 2.)

135. QUININE. $\text{C}_{20}\text{H}_{24}\text{N}_2\text{O}_2$ (Cinchona Bark).

1. Chlorine water, when added to an acid solution of quinine or its salts, produces no coloration until $(\text{NH}_4)\text{HO}$ is added, when a bright green colour is produced. If $\text{K}_4\text{Fe}(\text{CN})_6$ be added before the $(\text{NH}_4)\text{HO}$, a red coloration is produced, soon changing to dirty brown.

2. KHO or $(\text{NH}_4)\text{HO}$ produces, in solutions of quinine salts, a white amorphous precipitate of quinine,

which, on standing, becomes crystalline. The precipitate is scarcely soluble in KHO, but slightly soluble in $(\text{NH}_4)\text{HO}$. If a mixture of a quinine solution and $(\text{NH}_4)\text{HO}$ be shaken up with ether, the precipitated quinine is dissolved. (Compare test 2 for Cinchonine, 136.)

3. Solutions of quinine or its salts are fluorescent in a high degree, and possess an extremely bitter taste.

136. CINCHONINE. $\text{C}_{20}\text{H}_{24}\text{N}_2\text{O}$ (Cinchona Bark).

1. Chlorine water produces no coloration, even on addition of $(\text{NH}_4)\text{HO}$, which produces a yellowish precipitate.

2. KHO or $(\text{NH}_4)\text{HO}$ produces, in solutions of cinchonine salts, a white amorphous precipitate of cinchonine, insoluble in excess, and not dissolved when shaken up with ether. (Compare test 2 for Quinine, 135.)

3. Solutions of cinchonine have a bitter taste and an alkaline reaction. The salts are less soluble in water and alcohol than those of quinine.

137. URIC ACID. $\text{C}_5\text{H}_4\text{N}_4\text{O}_3$ (Urine).

1. HNO_3 dissolves uric acid with effervescence, and the solution when evaporated to dryness and moistened with $(\text{NH}_4)\text{HO}$ assumes a bright purple colour (murexide).

2. Na_2CO_3 solution dissolves uric acid. If this solution be placed on paper moistened with AgNO_3 solu-

tion, a brown stain is produced, owing to the reducing action of the uric acid.

138. UREA. $\text{CH}_4\text{N}_2\text{O}$ (Urine).

1. HNO_3 , when added to solutions of urea, unites with it, forming the nitrate, which separates out in crystalline plates, which are tolerably soluble in hot water and alcohol, but nearly insoluble in HNO_3 .

2. KHO added to urea decomposes it on heating, and NH_3 is evolved.

139. CHOLESTERINE. $\text{C}_{26}\text{H}_{44}\text{O}$ (Biliary Calculi).

1. KHO does not saponify cholesterine, although in many of its properties it resembles oils and fats.

2. Boiling alcohol dissolves cholesterine, and on cooling it crystallizes out in colourless plates.

140. GRAPE SUGAR. $\text{C}_6\text{H}_{12}\text{O}_6$ (Fruit, Honey, Diabetic Urine, &c.).

1. H_2SO_4 forms with grape sugar a definite compound of a yellow colour. No charring occurs as in the case of cane sugar.

2. Solution of grape sugar, when mixed with a few drops of CuSO_4 and excess of KHO , produces on boiling a red precipitate (Cu_2O), caused by the reducing action of the grape sugar. Solution of cane sugar does not give this reaction until boiled with a single drop of H_2SO_4 , which converts it into grape sugar.

141. ALBUMIN (White of Egg.)

1. Boiling water causes albumin to coagulate and it becomes at the same time insoluble, so that if a solution in cold water be heated, coagulation at once takes place.

2. Hg Cl_2 coagulates albumin, even when present in exceedingly small quantities. Coagulation also takes place with solutions of other salts, *e.g.* CuSO_4 , SnCl_2 , AgNO_3 .

142. STARCH. $\text{C}_6\text{H}_{10}\text{O}_5$ (Potato, Wheat, &c.). See 43, b.**143. TANNIC ACID. $\text{C}_{27}\text{H}_{22}\text{O}_{17}$ (Gall-nuts).**

1. Solution of gelatin (isinglass) produces a yellowish flocculent precipitate. A piece of animal membrane gives the same precipitate.

2. Fe_2Cl_6 produces a dark bluish black precipitate (ink).

144. GALLIC ACID. $\text{C}_7\text{H}_6\text{O}_5$ (Gall-nuts).

1. Solution of gelatin produces no precipitate.

2. Fe_2Cl_6 produces in neutral solutions a bluish black precipitate.

145. Detection of CARBON, HYDROGEN, and NITROGEN in ORGANIC BODIES :—

(a) CARBON.—Mix the substance intimately with powdered CuO , place in a hard glass tube, fill up with small pieces of CuO , and close the tube with a cork

through which a conducting tube passes into a flask containing clear lime-water. On heating, the carbon is oxidized to CO_2 , which renders the lime-water turbid. Organic liquids are examined in a similar way : they are placed in a small bulb-tube which is placed inside a hard glass tube and gently heated as soon as the CuO in front is red-hot. In this way the vapour passes over the CuO , and CO_2 is produced.

(*b*) HYDROGEN.—Proceed as in *a* (taking care to use perfectly dry CuO), but connect the conducting tube with a weighed CaCl_2 tube. Heat the hard glass tube as before, and then weigh the CaCl_2 tube. Gain in weight indicates that water has been formed by the oxidation of the hydrogen in the substance. When much water is present, it is visible in the bulb of the CaCl_2 tube.

(*c*) NITROGEN.—Mix the substance intimately with powdered soda-lime, and observe if NH_3 is given off on heating. Ascertain this by the smell and by the action on red litmus paper.

TABLE K.

146. Separation of Organic Acids.

Remove the metals of the Silver, Copper, and Iron Groups by their respective group reagents. Neutralize the solution with $(\text{N H}_4)\text{HO}$, add CaCl_2 , shake well, and allow to stand for at least twenty minutes.

PRECIPITATE.

FILTRATE.

Oxalic and Tartaric Acids.

Wash with water, add to precipitate cold NaHO and filter.

RESIDUE. FILTRATE.

 CaOx.

Confirm by tests 3 & 4, 100, to ascertain the presence of **Oxalic Acid.**

T.

Confirm by tests 3 & 4, 122, to ascertain the presence of **Tartaric Acid.**

Add to filtrate 3 volumes of strong alcohol, and filter.

PRECIPITATE.

Citric and Malic Acids.

Wash with alcohol, dissolve in HCl , add $(\text{N H}_4)\text{HO}$, boil and filter.

PRECIPITATE.

FILTRATE.

 CaCl.

Confirm by dissolving again in HCl and adding $(\text{NH}_4)\text{HO}$. Confirm by tests 4 and 5, 123, to ascertain the presence of **Citric Acid.**

 $\text{C}_4\text{H}_5\text{O}_5$.

Add alcohol, and test precipitate for **Malic Acid.**

Remaining Acids.Heat to expel alcohol, neutralize exactly with HCl , and add Fe_2Cl_6 . Filter.

FILTRATE.

Succinic and Benzoic Acids, &c.

Heat to expel alcohol, neutralize exactly with HCl , and add Fe_2Cl_6 . Filter.

PRECIPITATE.

FILTRATE.

Succinic and Benzoic Acids, &c. &c.

Wash the precipitate, warm with $(\text{NH}_4)\text{HO}$, boil down and divide into two parts (A and B).

Acetic and formic acids are tested for in the original solution. Neutralize (if necessary) with Na_2CO_3 , boil down to dryness, and test a portion for **Acetic Acid** by ether test 128, 3. Or distil with H_2SO_4 and digest distillate with excess of PbO to obtain basic acetate of lead. To another portion of dry residue add dilute H_2SO_4 and distil. Heat part of the distillate with PbO to obtain crystals of lead formate. To another part add $(\text{NH}_4)\text{HO}$ till neutral, and then AgNO_3 (test 1, 129), to ascertain the presence of **Formic Acid.**

A.

Add a mixture of BaCl_2 solution and alcohol. Precipitate indicates **Succinic Acid.** Confirm by test 4, 125.

B.

Add HCl to obtain shining crystals of **Benzoic Acid.** Confirm by test 3, 124.

Uric (137), tannic; and gallic acids are separately tested. Gallic and tannic are separated by isinglass, or by dialysis through a small piece of bladder (143 and 144).

PART V.

REACTIONS OF THE RARE METALS.

147. THE following rare metals are considered here by themselves, and their position in the various groups indicated. For their separation from each other and from the commonly occurring metals, a larger manual must be consulted.

Tungsten, Thallium, Palladium, Rhodium, Osmium, Ruthenium, Gold, Platinum, Iridium, Molybdenum, Selenium,* Tellurium, Uranium, Indium, Beryllium, Zirconium, Cerium, Lanthanum, Didymium, Titanium, Tantallum, Vanadium, Lithium, Cæsium, Rubidium.

* Selenium, although a metalloid, is conveniently included here.

Grouping of the Rare Metals.

148. PRECIPITATED IN SILVER GROUP.

Tungsten (as Tungstic Acid), Thallium (as Chloride).

PRECIPITATED IN COPPER GROUP.

Palladium, Rhodium, Osmium, Ruthenium.

PRECIPITATED IN ARSENIC GROUP.

Gold, Platinum, Iridium, Molybdenum, Tellurium, Selenium.

PRECIPITATED IN IRON GROUP.

Uranium, Indium (Thallium), *as sulphides*; Beryllium, Zirconium, Cerium, Lanthanum, Didymium, Titanium, Tantalum, *as hydrated oxides*.

PRECIPITATED AS SULPHIDES ON ADDING HCl TO THE FILTRATE FROM THE IRON GROUP.

Vanadium (Tungsten).

FOUND IN POTASSIUM GROUP.

Lithium, Cæsium, Rubidium.

Reactions of the Rare Metals of the Silver Group.**149. TUNGSTEN.** W, c.w. 184.

1. HCl produces a white precipitate of Tungstic acid H_2WO_4 , insoluble in excess, but soluble in $(\text{NH}_4)\text{HO}$. H_2SO_4 or HNO_3 produces the same precipitate.

2. $(\text{NH}_4)_2\text{S}$ does not precipitate tungstates of the alkalis, until an acid be added, when tungsten trisulphide WS_3 is precipitated as a light brown powder.

3. $\text{K}_4\text{Fe}(\text{CN})_6$ in acid solutions yields a reddish brown coloration, and on standing, a precipitate of the same colour.

4. SnCl_2 produces a yellow precipitate. On adding HCl and heating, the precipitate becomes blue.

5. Zn in presence of phosphoric acid produces a bright blue colour.

6. With microcosmic salt in the reducing flame a blue bead is obtained, which changes to red on heating with FeSO_4 .

150. THALLIUM. Tl, c.w. 204.

1. HCl in strong solutions produces a white precipitate of TlCl , soluble in a large quantity of water.

2. $(\text{NH}_4)_2\text{S}$ produces a black precipitate of Tl_2S , insoluble in $(\text{NH}_4)\text{HO}$, but soluble in HCl, H_2SO_4 and HNO_3 .

3. KI precipitates TlI (yellow) even in dilute solutions.

4. PtCl_4 precipitates a double chloride of thallium and potassium Tl_3PtCl_6 of an orange colour.

5. Zn added to thallium solutions precipitates the metal.

6. Thallium salts colour the lamp flame intensely green.

Reactions of the Rare Metals of the Copper Group.

151. PALLADIUM. Pd, c.w. 106·6.

1. H_2S precipitates PdS as a black powder, insoluble in $(\text{NH}_4)_2\text{S}$, and soluble in boiling HCl and aqua regia.

2. $\text{Hg}(\text{CN})_2$ precipitates palladium cyanide, $\text{Pd}(\text{CN})_2$, yellowish white and gelatinous, soluble in $(\text{NH}_4)\text{HO}$ and in HCl .

3. KI produces a black precipitate of PdI_2 .

4. KCl in strong solutions precipitates K_2PdCl_6 in yellow needles, insoluble in absolute alcohol, but soluble in water, forming a dark-red fluid.

152. RHODIUM. Rh, c.w. 104·4.

1. H_2S precipitates Rh_2S_3 (brown), especially in warm solutions; it is insoluble in $(\text{NH}_4)_2\text{S}$, but soluble in hot HNO_3 .

2. KHO produces a yellowish precipitate of $\text{Rh}(\text{HO})_3$, H_2O , soluble in excess of the reagent; on boiling the solution, brown $\text{Rh}(\text{HO})_3$ is precipitated.

3. Zn produces a precipitate of metallic rhodium.

4. Dry compounds when ignited in a current of hydrogen are reduced to metal, insoluble in aqua regia, but soluble on fusing with H_2SO_4 .

153. OSMIUM. Os, c.w. 199'2.

1. H_2S in presence of acid precipitates OsS (brownish black), insoluble in $(\text{NH}_4)_2\text{S}$.
2. OsO_4 (osmic acid) decolorizes indigo solution.
3. KI is decomposed with liberation of iodine.
4. Na_2SO_3 yields a violet coloration, and after a time OsSO_3 (deep blue) separates out.
5. FeSO_4 precipitates black OsO_2 .
6. Zn in presence of acids precipitates the metal.
7. Dry compounds when ignited in a current of hydrogen are reduced to metal.
8. The metal and the mono- and di-oxides, when heated in air, yield OsO_4 , which is recognized by its peculiar irritating smell (resembling chlorine). This is an exceedingly characteristic reaction.

154. RUTHENIUM. Ru, c.w. 104'4.

1. H_2S produces no immediate precipitate, but on standing, the solution turns blue, and brown Ru_2S_3 is precipitated.
2. $(\text{NH}_4)_2\text{S}$ precipitates Ru_2S_3 , difficultly soluble in excess.
3. KHO precipitates black sesquioxide $\text{Ru}(\text{HO})_3$, insoluble in excess, but soluble in acids.
4. KCNS in pure solutions produces on standing, a red coloration, which becomes first purple, and then on heating violet.
5. Zn produces a blue coloration, and ultimately the metal separates out.

TESTS FOR GOLD AND PLATINUM. 137

Reactions of the Rare Metals of the Arsenic Group.

155. GOLD. Au, c.w. 197.

1. H_2S produces in cold solutions black Au_2S_3 , in hot solutions brown Au_2S . Both precipitates are insoluble in HNO_3 and in HCl , but dissolve in aqua regia. They dissolve in yellow, but not in colourless ammonium sulphide.

2. $(\text{NH}_4)_2\text{S}$ produces a black precipitate of Au_2S_3 .

3. $(\text{NH}_4)\text{HO}$ in strong solutions precipitates ammonium aurate (fulminating gold).

4. FeSO_4 produces a precipitate of the metal, as a brown powder, which, when rubbed, assumes a yellow colour and metallic lustre.

5. KNO_3 also produces a precipitate of the metal.

6. $\text{SnCl}_2 + \text{SnCl}_4$ produce a purplish precipitate (purple of Cassius) even in highly dilute solutions; the precipitate is insoluble in HCl .

7. Heated on charcoal with Na_2CO_3 before the blow-pipe, malleable yellow beads of the metal are obtained. (See also flame reaction, 59.)

156. PLATINUM. Pt, c.w. 1975.

1. H_2S produces in cold solutions on standing, brown PtS_2 ; on heating, the precipitate forms at once. It is soluble in a large excess of yellow ammonium sulphide; it is insoluble in HCl and in HNO_3 , but soluble in aqua regia.

2. $(\text{NH}_4)_2\text{S}$ produces the same precipitate as H_2S .

3. NH_4Cl produces a yellow crystalline precipitate of $(\text{NH}_4)_2\text{PtCl}_6$, more sparingly soluble in alcohol than in water. On heating the dried precipitate, metallic platinum is left in a finely divided state.

4. KCl produces a yellow crystalline precipitate of K_2PtCl_6 , also more insoluble in alcohol than in water. On heating the dried precipitate, a mixture of Pt and KCl is obtained.

5. SnCl_2 produces no precipitate, but, in solutions containing HCl in excess, yields a dark brown coloration due to the formation of dichloride.

6. FeSO_4 on long-continued boiling produces a precipitate of the metal.

7. Fused on charcoal with Na_2CO_3 before the blow-pipe flame, yields the metal as an infusible grey powder. (See also flame reaction, 59.)

157. IRIDIUM. Ir , c.w. 198.

1. H_2S first removes the colour and sulphur separates out; afterwards brown iridium sulphide is precipitated.

2. $(\text{NH}_4)_2\text{S}$ produces the same precipitate, soluble in excess.

3. KCl produces a dark brown precipitate of K_2IrCl_6 , insoluble in a concentrated solution of the reagent.

4. NH_4Cl produces a dark red precipitate of $(\text{NH}_4)_2\text{IrCl}_6$.

5. FeSO_4 decolorizes solutions of iridium, but produces no precipitate.

6. Zn precipitates the metal as a black powder.

158. MOLYBDENUM. Mo, c.w. 96.

1. H_2S precipitates in warm solutions, after some time, brownish black MoS_3 , soluble in $(\text{NH}_4)_2\text{S}$.

2. Zn, in acid solutions, produces a blue coloration, which changes to green, and lastly to black, when Mo_2O_3 separates out.

3. KCNS, when added to an HCl solution, produces on addition of Zn a crimson coloration.

4. Na_2HPO_4 produces, in a nitric acid solution of ammonium molybdate, a yellow precipitate (in dilute solutions only after the lapse of some time). The precipitation is aided by *gentle* heating.

159. TELLURIUM. Te, c.w. 129.

1. H_2S produces, in presence of acid, a brown precipitate of TeS_2 , easily soluble in $(\text{NH}_4)_2\text{S}$.

2. H_2O produces a white precipitate of H_2TeO_3 .

3. KHO or Na_2CO_3 , when added to an HCl solution, produces a white precipitate of H_2TeO_3 , soluble in excess of either reagent.

4. Na_2SO_3 or SnCl_2 produces a black precipitate of the metal.

5. Zn precipitates the metal as a black powder.

6. Fused with Na_2CO_3 , yields Na_2Te , which, on treatment with HCl, yields H_2Te , recognized by its very disagreeable odour.

160. SELENIUM. Se, c.w. 79.5.

1. H_2S produces, in presence of acid, a yellow precipitate of doubtful composition, which darkens in colour on heating, and is soluble in $(\text{NH}_4)_2\text{S}$.

2. BaCl_2 produces a white precipitate of BaSe , soluble in HCl .

3. SO_2 and SnCl_2 produce in acid solutions a red precipitate of Se .

4. Heated in the reducing flame on charcoal, selenium compounds yield a highly characteristic smell, resembling that of horse-radish.

Reactions of the Rare Metals of the Iron Group.

161. URANIUM. U, c.w. 120.

1. $(\text{NH}_4)_2\text{S}$ produces a brown precipitate of oxysulphide, soluble in colourless ammonium sulphide to a black liquid.

2. Alkalies produce a yellow precipitate of hydrated oxide, insoluble in excess of the reagent.

3. $(\text{NH}_4)_2\text{CO}_3$ produces a precipitate of the double carbonate of uranium and ammonium, soluble in excess of the reagent.

4. BaCO_3 produces a precipitate of hydrated oxide in cold solutions.

5. $\text{K}_4\text{Fe}(\text{CN})_6$ produces a reddish brown precipitate.

6. Fused with borax in the reducing flame, uranium compounds yield pale green beads.

162. INDIUM. In, c.w. 113.

1. $(\text{NH}_4)_2\text{S}$, in presence of $(\text{NH}_4)\text{HO}$ and tartaric acid, produces a white precipitate, which turns yellow on addition of acetic acid.

2. Alkalies produce a precipitate of the hydrate, insoluble in excess of the reagent.

3. Alkaline carbonates precipitate the carbonate, soluble in excess of $(\text{NH}_4)_2\text{CO}_3$, but not in excess of K_2CO_3 or Na_2CO_3 .

4. BaCO_3 precipitates solutions of indium completely.

5. $\text{K}_4\text{Fe}(\text{CN})_6$ produces a white precipitate.

6. Zn precipitates the metal in shining plates.

7. Heated with Na_2CO_3 in the reducing blow-pipe flame, metallic beads are obtained.

8. Indium compounds impart a bluish violet tinge to the flame.

163. BERYLLIUM. Be, c.w. 9'3.

1. $(\text{NH}_4)_2\text{S}$ precipitates the hydrate (flocculent) like alumina in appearance, but differs from it in dissolving on continued boiling with NH_4Cl . Beryllium chloride is formed and ammonia is driven off.

2. KHO precipitates the hydrate, soluble in excess. If this solution be diluted and well boiled, the beryllium hydrate is re-precipitated.

3. Na_2CO_3 precipitates the carbonate (white), soluble in a large excess.

4. $(\text{NH}_4)_2\text{CO}_3$ precipitates the carbonate (white), easily soluble in excess of the reagent.

5. BaCO_3 in cold solutions precipitates the beryllium completely.

164. ZIRCONIUM. Zr, c.w. 89'6.

1. $(\text{NH}_4)_2\text{S}$ produces a precipitate of hydrate, in-

soluble in excess. KHO and $(\text{NH}_4)\text{HO}$ produce the same precipitate, insoluble in excess of these reagents.

2. Alkaline carbonates precipitate the carbonate as a flocculent powder, soluble in a large excess of K_2CO_3 and in a small excess of $(\text{NH}_4)_2\text{CO}_3$. From this latter solution the hydrate is re-precipitated on boiling.

3. BaCO_3 does not precipitate zirconium completely, even on boiling.

105. CERIUM. Ce, c.w. 92.

1. $(\text{NH}_4)\text{HO}$ produces a precipitate of a basic salt, insoluble in excess.

2. KHO produces a precipitate of the white hydrate, insoluble in excess of the reagent. The precipitate becomes yellow on exposure to the air.

3. $(\text{NH}_4)_2\text{CO}_3$ produces a white precipitate, soluble in excess of the reagent.

4. $\text{C}_2\text{H}_2\text{O}_4$ precipitates cerous oxalate, insoluble in excess, but soluble in HCl.

5. BaCO_3 precipitates cerium completely after the lapse of some time.

6. Chlorine, passed through a solution mixed with sodium acetate, precipitates the peroxide (light yellow).

106. LANTHANUM. La, c.w. 92.

1. $(\text{NH}_4)\text{HO}$ produces a precipitate of a basic salt.

2. KHO precipitates the hydrate (white), which does not alter on exposure to air.

3. $(\text{NH}_4)_2\text{CO}_3$ produces a precipitate, insoluble in excess of the reagent.

4. $C_2H_2O_4$ precipitates the oxalate, insoluble in excess, but soluble in HCl.

167. DIDYMIUM. D, c.w. 95.

1. $(NH_4)HO$ produces a precipitate of a basic salt, insoluble in excess of the reagent, but sparingly soluble in NH_4Cl .

2. KHO precipitates the hydrate (white), which does not alter on exposure to air.

3. $(NH_4)_2CO_3$ produces a white precipitate, insoluble in excess of the reagent, but soluble in NH_4Cl .

4. $C_2H_2O_4$ produces an almost complete precipitation of the oxalate, soluble in hot HCl.

5. Fused with microcosmic salt in the reducing flame, a reddish violet bead is obtained.

6. Fused with carbonate of soda in the oxidizing flame, greyish white beads are obtained.

168. TITANIUM. Ti, c.w. 50.

1. $(NH_4)HO$ or $(NH_4)_2S$ precipitates H_2TiO_3 (titanic acid), insoluble in excess of either reagent.

2. KHO also precipitates H_2TiO_3 , insoluble in excess.

3. $BaCO_3$ produces the same precipitate.

4. $Na_2S_2O_3$ when boiled with titanium solutions precipitates them completely.

5. Zn produces, first a blue coloration, then a blue precipitate, which ultimately becomes white.

6. Fused with $FeSO_4$ and microcosmic salt in the reducing flame, a bright red bead is obtained.

Reactions of the Rare Metals precipitated as Sulphides on adding HCl to the filtrate from the Iron Group.

169. VANADIUM. V, c.w. 51'3.

1. H_2S produces no precipitate in acid solutions, but a blue coloration by reducing to a lower oxide.

2. $(\text{NH}_4)_2\text{S}$ produces in a solution containing H_2SO_4 a brown precipitate of the sulphide, soluble in excess of the reagent.

3. NH_4Cl in solutions of alkaline vanadates, precipitates the metal completely as ammonium metavanadate (white). This precipitate loses ammonia on heating, and leaves a residue of V_2O_5 .

4. $\text{K}_4\text{Fe}(\text{CN})_6$ produces, in acid solutions, a green precipitate, not dissolved by acids.

5. SO_2 , or oxalic acid, reduces acid solutions of V_2O_5 to a lower oxide of vanadium, of a bright blue colour.

6. Zn, added to a solution of V_2O_5 in H_2SO_4 (diluted with H_2O), produces a series of changes in colour, and ultimately a violet solution is obtained, which rapidly becomes brown in air by oxidation.

Reactions of the Rare Metals found in Potassium Group.

170. LITHIUM. Li, c.w. 7.

1. Pt.Cl_4 produces no precipitate.

2. Na_2HPO_4 produces, on boiling the solution, a white precipitate of $2\text{Li}_3\text{PO}_4 + \text{H}_2\text{O}$. The precipitate

is soluble in HCl , and is not re-precipitated by $(\text{NH}_4)\text{HO}$ unless the solution be boiled.

3. Lithium compounds tinge the lamp flame bright crimson.

171. CÆSIUM. Cæ, c.w. 133.

1. PtCl_4 produces a crystalline light yellow precipitate of $2(\text{CæCl}) + \text{PtCl}_4$, insoluble in boiling water. (The corresponding potassium salt is dissolved by repeated treatment with boiling water.)

2. Tartaric acid produces a precipitate of the acid tartrate of cæsium, more soluble in water than the corresponding compound of rubidium.

3. Volatile cæsium salts colour the flame violet.

172. RUBIDIUM. Rb, c.w. 85.4.

1. PtCl_4 produces a crystalline light yellow precipitate of $2(\text{RbCl}) + \text{PtCl}_4$, insoluble in boiling water.

2. Tartaric acid produces a precipitate of the acid tartrate of rubidium, which is much more insoluble in water than the corresponding cæsium compound.

3. Volatile salts of rubidium colour the flame violet.



APPENDIX.

**TABLE OF THE ELEMENTS, WITH THEIR
SYMBOLS AND COMBINING WEIGHTS.**

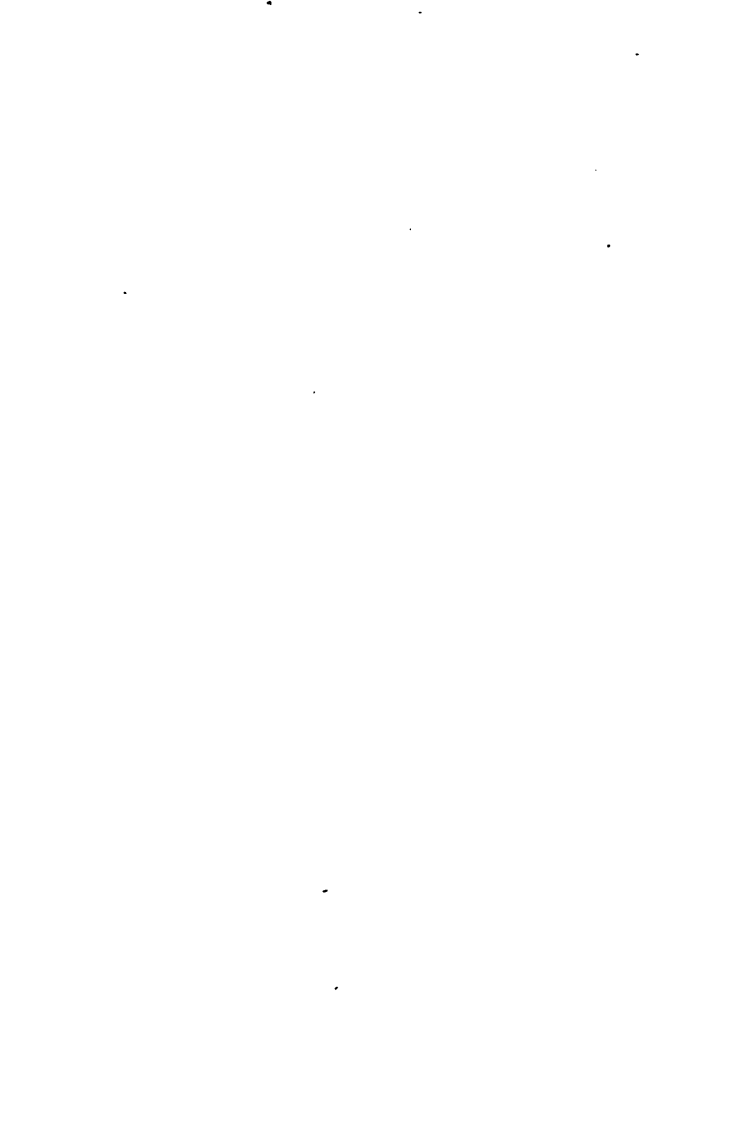
Element.	Symbol.	Combining Weight.
Aluminium	Al	27'4
Antimony	Sb	122
Arsenic	As	75
Barium	Ba	137
Beryllium	Be	9'3
Bismuth	Bi	210
Boron	B	11
Bromine	Br	80
Cadmium	Cd	112
Cæsium	Cs	133
Calcium	Ca	40
Carbon	C	12
Cerium	Ce	92
Chlorine	Cl	35'5
Chromium	Cr	52'2
Cobalt	Co	58'7
Copper	Cu	63'5
Didymium	D	95
Erbium	E	112'6

Element.	Symbol.	Combining Weight.
Fluorine	F	19
Gold	Au	197
Hydrogen	H	1
Indium	In	113
Iodine	I	127
Iridium	Ir	198
Iron	Fe	56
Lanthanum	La	92
Lead	Pb	207
Lithium	Li	7
Magnesium	Mg	24
Manganese	Mn	55
Mercury	Hg	200
Molybdenum	Mo	96
Nickel	Ni	58.7
Niobium	Nb	94
Nitrogen	N	14
Osmium	Os	199.2
Oxygen	O	16
Palladium	Pd	106.6
Phosphorus	P	31
Platinum	Pt	197.5
Potassium	K	39.1
Rhodium	Rh	104.4
Rubidium	Rb	85.4
Ruthenium	Ru	104.4
Selenium	Se	79.5
Silver	Ag	108

TABLE OF THE ELEMENTS.

149

Element.	Symbol.	Combining Weight.
Silicon	Si	28
Sodium	Na	23
Strontium	Sr	87.5
Sulphur	S	32
Tantalum	Ta	192
Tellurium	Te	129
Thallium	Tl	204
Thorium	Th	231.5
Tin	Sn	118
Titanium	Ti	50
Tungsten	W	184
Uranium	U	120
Vanadium	V	51.3
Yttrium	Y	61.6
Zinc	Zn	65.2
Zirconium	Zr	89.6



QUESTIONS AND EXERCISES.

3. (a) How many grams of oxygen can be obtained by heating 1,080 grams of mercuric oxide?

(b) Twenty-four grams of oxygen are required; how much mercuric oxide must be heated?

4. (a) What is left when potassium chlorate is heated?

(b) How many grams of potassium chlorate must be heated in order to yield 500 grams oxygen?

(c) How much potassium chloride will remain after heating 247 grams potassium chlorate?

5. How is potassium chlorate distinguished from potassium chloride?

6. (a) Describe the best means of preparing oxygen?

(b) The residue in a flask used to prepare oxygen, consisted of 13 grams of potassium chloride; how much chlorate had been heated, and how much oxygen evolved?

(c) Why is manganese dioxide mixed with potassium chlorate in preparing oxygen?

8. (a) What happens when a taper is burned in oxygen?

(b) How is the presence of carbon dioxide generally ascertained?

9. (a) 1.4 gram of charcoal containing 96 per cent. of carbon is burnt in oxygen; how much carbon dioxide is produced?

(b) Contrast the burning of a candle with the breathing of an animal in air.

10. How much oxygen is required to burn 42 grams of sulphur to sulphur dioxide?

11. How much phosphoric anhydride can be obtained by burning 2.34 grams phosphorus in oxygen, and how much phosphoric acid would be obtained by dissolving the anhydride in water?

12. (a) How much hydrogen can be got by dissolving 15 ounces of zinc in sulphuric acid?

(b) Which will yield the greater quantity of hydrogen when dissolved in acids—162 grams zinc, or 140 grams iron? Why?

13. How much water will be formed by burning all the hydrogen evolved by dissolving 3.42 grams zinc in sulphuric acid?

14. How much zinc sulphate should be got by dissolving 1 lb. zinc in sulphuric acid?

15. How is nitrogen prepared?

16. One hundred grams of potassium nitrate are heated with sulphuric acid; how much nitric acid and hydrogen potassium sulphate will be obtained?

17. What are the best tests for nitric acid?

24. (a) How is ammonia gas prepared, and what is the residue from its preparation?

(b) How much ammonium chloride must be used to obtain 291 grams ammonia gas?

25. How is ammonia tested for?

27. (a) How is ammonium nitrate prepared?

(b) How much ammonium nitrate can be got from 327 grams of nitric acid?

28. How much nitrous oxide can be obtained from 437 grams of ammonium nitrate?

29. How can nitrous oxide be distinguished from oxygen?

30. If 7 grams of copper be acted on with nitric acid, how much nitric oxide will be obtained, and how much copper nitrate will remain?

31. Mention some of the properties of nitric oxide.

32. (a) How is carbon dioxide prepared from marble?

(b) How much hydrochloric acid will be needed exactly to decompose a kilogram of marble?

33. What reaction takes place when carbon dioxide and lime-water are brought together? Give the equation.

34. (a) How is carbon monoxide prepared from formic acid, and from oxalic acid?

(b) How much carbon monoxide should be obtained from 12 grams oxalic acid?

35. What happens when a mixture of carbon monoxide and dioxide is shaken up with caustic soda?

36. (a) Give the equation for the preparation of chlorine from common salt, manganese dioxide, and sulphuric acid?

(b) What is the action of hydrochloric acid on manganese dioxide?

(c) How much chlorine can be got by heating 560 grams manganese dioxide with salt and sulphuric acid?

(d) How much can be got by heating the same quantity with hydrochloric acid?

37. (a) Mention the chief properties of chlorine.

(b) How does chlorine act as a bleaching agent?

38. How much common salt is needed to prepare 109 kilograms of hydrochloric acid?

39. (a) What is meant by "neutralizing" an acid solution?

(b) What is meant by the terms "acids," "bases," and "salts"?

40. (a) Give the equation for the preparation of bleaching powder from lime and chlorine.

(b) How much chlorine is needed to convert 5 tons of slaked lime into bleaching powder?

41. (a) What happens when each of the following acids is brought in contact with calcium hypochlorite, sulphuric, nitric and hydrochloric?

(b) How can a solution of hypochlorous acid be distinguished from a solution of chlorine?

42. (a) Give the equation for the preparation of iodine from potassium iodide.

(b) Thirty-seven grams of iodine were obtained; how much potassium iodide was used?

43. What is the best test for free iodine ?

44. (a) How is sodium iodide prepared ?

(b) How much sodium iodide can be got from 20 grams of iodine ?

45. How much bromine can be got from 85 grams potassium bromide ?

46. How much sodium, bromate and bromide, should be obtained by dissolving 97 grams bromine in caustic soda ?

47. (a) How is hydrofluoric acid prepared ?

(b) What is its action upon glass, and how may it be used to etch glass ?

48. (a) What is the action of strong sulphuric acid upon copper ?

(b) How much sulphuric acid and copper must be used to obtain a kilogram of sulphur dioxide ?

(c) What is the action of sulphur dioxide upon nitric acid, and upon potassium chromate solution ?

50. (a) Describe in detail how sulphuretted hydrogen gas is prepared.

(b) How much ferrous sulphide must be used to obtain 42 grams of the gas ?

51. (a) How does sulphuretted hydrogen serve to divide the metals into groups ?

(b) How could you separate by means of sulphuretted hydrogen a solution containing copper, iron, and sodium ?

52. How is sodium hydrate prepared ?

54. (a) What is meant by the terms "oxidizing" and "reducing" flames ?

(b) How is each obtained, and for what is each used?

55. (a) How would you distinguish, by means of the blow-pipe, salts of the following metals—copper, cobalt, lead, zinc, antimony, aluminium, chromium, and strontium?

(b) What happens when mercuric chloride is heated on charcoal along with sodium bi-carbonate in the blow-pipe flame?

56. Name the substance which produces each of the following reactions:—

(a) Bead brittle, soluble in nitric acid, sulphide black.

(b) No metallic bead, but incrustation of oxide on charcoal (brown).

(c) Bead malleable, soluble in nitric acid; solution gives with sulphuric acid a white precipitate.

(d) No metallic bead, after heating; moistening with cobalt chloride and re-heating gives a pink residue.

(e) Red bead, soluble in nitric acid; solution becomes bright blue on adding ammonia: borax bead blue.

(f) No metallic bead: borax bead amethyst coloured in reducing flame.

57. (a) How may a Bunsen lamp flame be substituted for the flames obtained by the mouth blow-pipe?

(b) Which is the hottest part of the Bunsen lamp flame, and which part has most reducing power?

(c) How are metallic films and metallic beads obtained by Bunsen's flame reactions?

58. How can arsenic, mercury, thallium, cadmium,

gold and platinum be distinguished by Bunsen's flame reactions?

59. Give Bunsen's reactions for zinc, mercury, bismuth, lead, copper, and iron.

60. Give Bunsen's tests for phosphorus and sulphur, and state the reactions involved in each.

61. Six substances gave the following reactions when examined by means of Table A. Name each substance.

(a) Water evolved on heating (reaction acid). Substance dissolved in water, and on adding HCl a gas was evolved smelling of burning sulphur. None of the group reagents gave a precipitate. Flame coloration, yellow.

(b) Nitrogen tetroxide evolved on heating. Substance dissolved in water, and gave a white precipitate with hydrochloric acid, soluble in hot water.

(c) Oxygen evolved on heating. Substance insoluble in water, but dissolved by heating with hydrochloric acid with evolution of chlorine. No precipitate with HCl, or with $\text{HCl} + \text{H}_2\text{S}$, but on adding $(\text{NH}_4)\text{HO} + \text{NH}_4\text{Cl} + (\text{NH}_4)_2\text{S}$ a flesh-coloured precipitate was obtained.

(d) Carbon dioxide evolved on heating strongly. Substance insoluble in water, but on adding HCl a gas was evolved with effervescence, which rendered lime-water turbid. No precipitate with the first three group reagents, but a white one with $(\text{NH}_4)\text{HO} + \text{NH}_4\text{Cl} + (\text{NH}_4)_2\text{CO}_3$. Flame coloration dull red.

(e) White sublimate on heating. Substance dissolved in water and gave no precipitate with BaCl_2 , but a white one with AgNO_3 , insoluble in NH_4OH . No precipitate with any of the group reagents, but gave a smell of ammonia on heating with NaHO .

(f) Oxygen evolved on heating. Substance soluble in water, gave no precipitate with the first three group reagents, but a white one with $(\text{NH}_4)\text{HO} + \text{NH}_4\text{Cl} + (\text{NH}_4)_2\text{CO}_3$. Flame coloration green.

61. Six substances gave the following reaction when examined by means of Table B. Name each substance.

(a) White and unfused on heating. Yields when heated on charcoal with sodium carbonate, a malleable bead which leaves a black mark on paper.

(b) Infusible and disappears on heating. Deflagrates when heated with potassium nitrate.

(c) Infusible when heated. Microcosmic salt bead colourless. Blue mass after heating on charcoal, moistening with CoCl_2 and heating again.

(d) White and infusible. When heated with H_2SO_4 , evolves gas which etches glass.

(e) Infusible, but darkens in colour on heating. Fused with NaHCO_3 , yields a brittle bead.

(f) Fused but not volatilized on heating. Yields malleable metallic bead when heated on charcoal with NaHCO_3 .

62. (a) Give the four group reagents, and state the metals precipitated by each.

(b) What are the metals of Group V.?

63. Write out the tests for silver.

64. Write out the tests for mercurous salts.

65. (a) Write out the tests for lead.

(b) How is lead chloride distinguished from the chlorides of silver and mercury?

(c) Give two methods for separating lead from silver and mercury.

66. How can you separate the metals in a solution containing silver, mercury, and lead?

67. (a) What happens when H_2S is added to a solution of a mercuric salt?

(b) What is "white precipitate"?

68. Why does lead occur both in the silver and copper groups?

69. (a) What is the action of water on salts of bismuth?

(b) How is lead chromate distinguished from bismuth chromate?

70. (a) What is the action of KCN and of H_2SO_4 upon copper sulphide?

(b) What happens when $(NH_4)HO$ is added to a solution of copper sulphate?

71. (a) What is the action of KCN and of H_2SO_4 upon cadmium sulphide?

(b) Give two methods for the separation of copper from cadmium.

72. (a) Why is the filtrate from the silver group boiled down with hydrochloric acid before precipitating with H_2S ?

(b) What is the action of $(NH_4)_2S_3$ on the sul-

phides of the following metals—lead, antimony, copper, bismuth, tin, and cadmium?

(c) What is the action of nitric acid upon sulphides of copper, mercury, bismuth, and cadmium?

73. (a) What reactions take place when mercuric chloride is added to stannic chloride and stannous chloride?

(b) How is purple of Cassius obtained?

74. (a) What is the reaction of zinc upon an acid solution of antimony contained in a platinum vessel?

(b) Describe Marsh's test for antimony.

(c) What is the action of sulphuretted hydrogen upon an antimony mirror?

75. (a) What is the action of silver nitrate upon an acid, neutral, and alkaline solution of arsenious acid?

(b) Give the formula of Scheele's green, and state how it may be obtained.

(c) Describe Marsh's test for arsenic, and point out how it serves to distinguish that metal from antimony.

(d) Describe Reinsch's test for arsenic.

(e) Mention several ways of distinguishing an antimony from an arsenic mirror.

(f) State all the dry reactions for arsenic.

76. (a) What is the action of ammonium carbonate upon the sulphides of arsenic, antimony, and tin?

(b) How is tin separated from antimony?

77. (a) How is Prussian blue obtained, and what is its formula?

(b) How is Turnbull's blue obtained?

(c) How are ferrous and ferric salts distinguished by the ferro- and ferri-cyanides of potassium?

78. (a) When a solution of the metals of the iron group is precipitated with ammonium sulphide, what causes the filtrate to have a brown colour?

(b) What are the blow-pipe tests for nickel?

79. (a) What is the action of potassium cyanide upon solutions of nickel and cobalt?

(b) How would you separate a solution of the chlorides of nickel and cobalt?

(c) What is the action of potassium nitrite upon solutions of nickel and cobalt?

80. How can a solution of zinc hydrate in caustic potash be re-precipitated?

81. (a) How can a solution of aluminium hydrate in caustic potash be re-precipitated?

(b) How can you distinguish between the hydrate and phosphate of aluminium?

82. (a) What happens when ammonia is added to a solution of manganese containing ammonium chloride?

(b) What substance is formed when manganese compounds are fused with a mixture of potassium nitrate and carbonate?

(c) How would you separate a solution containing the nitrates of iron, zinc, and manganese?

83. (a) How would you separate analytically a solution of nickel, cobalt, and chromium?

(b) How would you separate analytically a solution containing iron, zinc, chromium, and manganese?

84. (a) What is the action of hydrochloric acid

upon the sulphides of iron, zinc, nickel, manganese, and cobalt?

(b) What is the action of barium carbonate upon a cold solution of each of the following metals—iron, nickel, zinc, chromium, and manganese?

(c) How is aluminium distinguished from zinc?

85. Mention three characteristic tests for barium.

86. How is strontium distinguished from barium?

87. How are strontium and calcium distinguished from each other?

88. (a) What is the action of strong alcohol upon the chlorides of barium and strontium, and upon the nitrates of strontium and calcium?

(b) How are barium, strontium, and calcium separated from each other?

(c) What is the action of acetic acid upon the chromates of barium and strontium?

89. What are the tests for magnesium?

90. What is precipitated on adding platinum chloride to potassium chloride? Give its formula.

91. (a) What is the action of platinum chloride upon ammonium chloride? Give its formula.

(b) How are ammonium salts distinguished from those of potassium?

92. How are potassium salts distinguished from those of sodium?

93. Describe how magnesium, potassium, sodium, and ammonium are separated.

94. How are organic and inorganic acids distinguished?

95. Write out the acids which occur in each of the four groups into which inorganic acids are divided.

96. How are sulphates detected by the blow-pipe?

97. What happens when sulphuric acid is heated with silico-fluorides?

98. (a) How does sodium phosphate behave with solutions of the following reagents—magnesium sulphate, lead acetate, ferric chloride, and ammonium molybdate?

(b) How is phosphoric acid separated from solutions of phosphates insoluble in water?

(c) Give the distinguishing tests for ortho-, pyro-, and meta-phosphoric acids.

99. How is borax recognized by a flame reaction?

100. (a) What reaction takes place when calcium chloride solution is added to an oxalate, and what happens when the resulting substance is ignited?

(b) How are oxalates distinguished from phosphates?

101. What is the most characteristic test for fluorides?

102. What is the most characteristic test for carbonates?

103. How is silicic acid obtained from a soluble silicate, and how is it converted into silicon dioxide?

104. State how chromic, arsenious, sulphurous, iodic, and arsenic acids are detected in the examination for bases.

105. How is sulphurous converted into hydro-sulphuric acid?

106. How are sulphites distinguished from hyposulphites?

108. How is arsenious distinguished from arsenic acid?

109. What is the effect of heat upon iodates, and upon iodic acid?

110. What happens when sulphur dioxide is passed through a solution of potassium chromate?

111. How is chromium oxychloride prepared from common salt and potassium bichromate?

112. (a) How is bromine liberated from its compounds, and how is its presence recognized?

(b) What happens when bromides are distilled with manganese dioxide and sulphuric acid?

113. (a) How is iodine liberated from potassium iodide, and how is its presence recognized?

(b) How can you detect chlorides, bromides, and iodides in presence of each other?

114. (a) How is silver chloride distinguished from silver cyanide?

(b) How may ammonium sulpho-cyanide be obtained from sodium cyanide, and from mercuric cyanide?

115. (a) How is hypochlorous acid obtained from calcium hypochlorite?

(b) Give equations for the reactions which occur when hydrochloric acid and sulphuric acid act upon sodium hypochlorite.

116. What are the tests for nitrous acid?

117. How is free sulphuretted hydrogen obtained from sulphides, and how is it recognized?

118. Give all the reactions for nitric acid.

119. (a) How is chloric distinguished from nitric acid?

(b) How is anhydrous perchloric acid obtained?

(c) How are perchlorates distinguished from chlorates?

120. (a) How is arsenious separated from phosphoric acid?

(b) Name the acids whose silver salts are insoluble in nitric acid.

(c) How are acids detected in insoluble bodies?

(d) How can barium sulphate be decomposed?

121. State the group reagents of the organic acids, and show how they are divided into groups.

122. What is the action of caustic potash upon calcium tartrate?

123. How is tartaric distinguished from citric acid? Give two methods.

125. How are succinic and benzoic acids distinguished?

127. What is the difference between the action of silver nitrate upon ferro- and upon ferri-cyanides?

129. Name the distinguishing tests for formic and acetic acids.

130. How is a soap formed from stearic acid, and how may the fat be separated?

131. What reactions are produced by ferric chloride, and iodic acid upon morphine?

132. How is morphine separated from meconic acid?

133. Name the characteristic tests for strychnine.

INDEX.

A.

Acetic acid, reactions of, 122
 Acids, bases, and salts, 30
 Acids, grouping of the inorganic, 97
 Albumin, reactions of, 129
 Aluminium, reactions of, 85
 Ammonia, preparation of, 16
 properties of, 18
 residue from preparation of, 18
 Ammonium, reactions of, 95
 Ammonium nitrate, preparation of, 19
 Antimony, reactions of, 73
 Arsenic, dry reactions for, 78.
 reactions of, 76
 Arsenic acid, reactions of, 107
 Arsenious acid, reactions of, 106

B.

Barium, reactions of, 90
 Benzoic acid, reactions of, 120
 Beryllium, reactions of, 141
 Bismuth, reactions of, 67
 Blow-pipe reactions, 43
 confirmatory tests, 44
 use of, 41
 Boric acid, reactions of, 102
 Bromine, preparation of, 34
 properties of, 34
 Brucine, reactions of, 126
 Bunsen's flame reactions, 46

C.

Cadmium, reactions of, 69
 Cæsium, reactions of, 145
 Calcium hypochlorite, preparation of,
 31

Calcium, reactions of, 91
 Cane sugar, reactions of, 128
 Carbon, detection of, in organic bodies,
 129
 Carbonic acid, reactions of, 104
 Carbon dioxide, preparation of, 22
 properties of, 23
 Carbon monoxide, preparation of, 24
 properties of, 24
 Cerium, reactions of, 142
 Chloric acid, reactions of, 113
 Chlorine, bleaching action of, 28, 31
 preparation of, 26
 properties of, 27
 Cholesterine, reactions of, 128
 Chromic acid, reactions of, 107
 Chromium, reactions of, 87
 Cinchonine, reactions of, 127
 Citric acid, reactions of, 120
 Cobalt, reactions of, 84
 Copper, reactions of, 68

D.

Didymium, reactions of, 143.

F.

Ferri-cyanic acid, reactions of, 122
 Ferric salts, reactions of, 82
 Ferro-cyanic acid, reactions of, 122
 Ferrous salts, reactions of, 81
 Formic acid, reactions of, 123

G.

Gallie acid, reactions of, 129
 Gold, reactions of, 137
 Grape sugar, reactions of, 128

H.

- HYDRIODIC acid**, reactions of, 110
Hydrobromic acid, reactions of, 109
Hydrochloric acid, preparation of, 28
 properties of, 30
 reactions of, 108
Hydrocyanic acid, reactions of, 111
Hydrofluoric acid, preparation of, 35
 properties of, 35
 reactions of, 103
Hydro-fluosilicic acid, reactions of, 99
Hydrogen, detection of, in organic bodies, 130
 preparation of, 9
 properties of, 11, 12
 residue from preparation of, 11
Hydro-sulphuric acid, reactions of, 113
Hypochlorous acid, preparation of, 31
 reactions of, 112
Hypo-sulphurous acid, reactions of, 106

I.

- INDIUM**, reactions of, 140
Iodic acid, reactions of, 107
Iodine, preparation of, 32
 properties of, 32
 tests for, 33
Iridium, reactions of, 138
Iron, reactions of, 81

L.

- LANTHANUM**, reactions of, 142
Lead, reactions of, 64, 67
Lithium, reactions of, 144

M.

- MAGNESIUM**, reactions of, 94
Manganese, reactions of, 86
Marsh's test for antimony, 73
 for arsenic, 77
Meconic acid, reactions of, 124
Mercuric salts, reactions of, 66
Mercurous salts, reactions of, 63
Metallic beads, 48
Metallic films, 48

- Metals**, grouping of the, 60
Metaphosphoric acid, reactions of, 101
Molybdenum, reactions of, 139
Morphine, reactions of, 124

N.

- NICKEL**, reactions of, 83
Nitrates, tests for, 16
Nitric acid, preparation of, 14
 reactions of, 15, 113
Nitrogen, preparation of, 12
 properties of, 13
 detection of, in organic bodies, 130
Nitrogen dioxide, preparation of, 20
 properties of, 21
Nitrogen monoxide, preparation of, 19
 properties of, 20
Nitrous acid, reactions of, 112

O.

- OPIMUM solutions**, reactions of, 125
Organic acids, grouping of the, 118
Osmium, reactions of, 136
Oxalic acid, reactions of, 102
Oxidation by blow-pipe, 42
Oxidizing flame, 41
Oxygen, combustions in, 5 to 8
 preparation of, from potassium chlorate and manganese dioxide, 4
 from mercuric oxide, 2
 from potassium chlorate, 3
 presence of, in air, 9
 residue from preparation of, 5

P.

- PALLADIUM**, reactions of, 135
Perchloric acid, reactions of, 114
Phosphoric acid, reactions of, 100
Phosphorus, blow-pipe test for, 54
Platinum, reactions of, 137
Potassium, reactions of, 94
Pyrophosphoric acid, reactions of, 101

Q.

- QUININE**, reactions of, 126

R.

RARE metals, grouping of the, 133
Reducing flame, 41
Reduction by blow-pipe, 42
Rhodium, reactions of, 135
Rubidium, reactions of, 145
Ruthenium, reactions of, 136

S.

SELENIUM, reactions of, 139
Silicic acid, reactions of, 104
Silver group, metals of the, 63
Silver, reactions of, 63
Single salts, preliminary examination of, 55
Sodium bromide, preparation of, 35
properties of, 35
Sodium hydrate, preparation of, 39
properties of, 40
Sodium iodide, preparation of, 33
properties of, 33
Sodium, reactions of, 95
Stannic salts, reactions of, 72
Stannous salts, reactions of, 72
Starch, reactions of, 129
Stearic acid, reactions of, 123
Stirring rods, 1
Strontium, reactions of, 90
Strychnine, reactions of, 125
Succinic acid, reactions of, 121
Sulphur, blow pipe test for, 55
Sulphur dioxide, preparation of, 36
properties of, 37
Sulphuretted hydrogen, preparation of, 37
properties of, 38
Sulphuric acid, reactions of, 99
Sulphurous acid, reactions of, 105

T.

TABLE A, examination of soluble single salts, 56
B, examination of insoluble substances, 58
C, separation of silver group, 65
D, " copper, 70
E, " arsenic, 80
F, " iron, 88
G, " calcium, 92
H, " potassium, 96
J, detection of inorganic acids, 115
K, separation of organic acids, 131
Tannic acid, reactions of, 129
Tartaric acid, reactions of, 119
Tellurium, reactions of, 139
Thallium, reactions of, 134
Titanium, reactions of, 143
Tungsten, reactions of, 134

U.

URANIUM, reactions of, 140
Urea, reactions of, 128
Uric acid, reactions of, 127

V.

VANADIUM, reactions of, 144

W.

WASH bottle, 2

Z.

ZINC, reactions of, 85
Zirconium, reactions of, 141

Aristotle. — AN INTRODUCTION TO ARISTOTLE'S RHETORIC. With Analysis, Notes, and Appendices. By E. M. COPE, Senior Fellow and Tutor of Trinity College, Cambridge. 8vo. \$3.

The author has aimed to illustrate the general bearings and relations of the Art of Rhetoric in itself, as well as the special mode of treating it adopted by Aristotle in his peculiar system. The evidence upon obscure or doubtful questions connected with the subject is examined; and the relations which Rhetoric bears, in Aristotle's view, to the kindred art of Logic are considered. A connected Analysis of the treatise is given, sometimes in the form of paraphrase; and a few important matters are separately discussed in Appendices. There is added, as a general Appendix, by way of specimen of the antagonistic system of Isocrates and others, a complete analysis of the treatise called 'Ῥητορική πρὸς Ἀλέξανδρον, with a discussion of its authorship and of the probable results of its teaching.

ARISTOTLE ON FALLACIES; OR, THE SOPHISTICAL ELENCHI. With a Translation and Notes by EDWARD POSTE, M.A., Fellow of Oriel College, Oxford. 8vo. \$4.50.

Besides the doctrine of Fallacies, Aristotle offers, either in this treatise or in other passages of his works quoted in the commentary, various glances over the world of science and opinion, various suggestions or problems which are still agitated, and a vivid picture of the ancient system of dialectics. "It is not only scholarlike and careful, it is also perspicuous."—GUARDIAN. "It is indeed a work of great skill."—SATURDAY REVIEW.

Blackie.—GREEK AND ENGLISH DIALOGUES FOR USE IN SCHOOLS AND COLLEGES. By JOHN STUART BLACKIE, Professor of Greek in the University of Edinburgh. Fcap. 8vo. \$1.

"Why should the old practice of conversing in Latin and Greek be altogether discarded?"—PROFESSOR JOWETT.

Professor Blackie has been in the habit, as part of the regular training of his class in Edinburgh University, of accustoming the students

to converse in Greek. This method he has found to be eminently successful as a means of furnishing the students with a copious vocabulary, training them to use it promptly, confidently, and with correct articulation, and instilling into them an accurate and intelligent knowledge of Greek Grammar, which he hopes may aid other teachers in realizing the same ends. The present little volume furnishes a series of twenty-five graduated dialogues in parallel columns of Greek and English on a great variety of interesting subjects. The Author has had the advantage of submitting his work to the judgment of several scholars of repute, both English and Scotch. The *GLOBE* says: "Professor Blackie's system is sensible; his book is likely to be useful to teachers of Greek; and his suggestions valuable to the learners of any language."

Cicero.—THE SECOND PHILIPPIC ORATION. With an Introduction and Notes, translated from the German of KARI HALM. Edited, with Corrections and Additions, by JOHN E. B. MAYOR, M.A., Fellow and Classical Lecturer of St. John's College, Cambridge. Third Edition, revised. Fcap. 8vo. \$1.25.

This volume opens with a List of Books useful to the Student of Cicero, and some account of various editions, mostly German, of the works of Cicero. The Introduction is based on Halm. The English editor has further illustrated the work by additions drawn, for the most part, (1) from the ancient authorities; (2) from his own private marginal references, and from collections; (3) from the notes of previous commentators. A copious 'argument' is also given. "On the whole we have rarely met with an edition of a classical author which so thoroughly fulfils the requirements of a good school-book."—*EDUCATIONAL TIMES.*
"A valuable edition," says the *ATHENÆUM*.

THE ORATIONS OF CICERO AGAINST CATILINA. With Notes and an Introduction. Translated from the German of Karl Halm, with many additions by A. S. WILKINS, M.A. Professor of Latin in Owens College, Manchester. Fcap. 8vo. \$1.25.

The historical introduction of Mr. Wilkins brings together all the details which are known respecting Catiline and his relations with

the great orator. A list of passages where conjectures have been admitted into the text, and also of all variations from the text of Kayser (1862), is added at the end. Finally, the English Editor has subjoined a large number of notes, both original and selected, from Curtius, Schleischer, Corssen, and other well-known critics, an analysis of the orations, and an index.

Demosthenes.—**DEMOSTHENES ON THE CROWN.** The Greek Text with English Notes. By B. DRAKE, M.A., late Fellow of King's College, Cambridge. Fourth Edition, to which is prefixed **ÆSCHINES AGAINST CTESIPHON**, with English Notes. Fcap. 8vo. \$1.50.

An Introduction discusses the immediate causes of the two orations, and their general character. The Notes contain frequent references to the best authorities. Among the appendices at the end is a chronological table of the life and public career of Æschines and Demosthenes. "A neat and useful edition."—ATHENÆUM.

Hodgson.—**MYTHOLOGY FOR LATIN VERSIFICATION.** A brief Sketch of the Fables of the Ancients, prepared to be rendered into Latin Verse for Schools. By F. HODGSON, B.D., late Provost of Eton. New Edition, revised by F. C. HODGSON, M.A. 18mo. 75 Cents.

The late Provost of Eton has here supplied a help to the composition of Latin Verse, combined with a brief introduction to Classical Mythology. In this new edition a few mistakes have been rectified; rules have been added to the Prosody; and a more uniform system has been adopted with regard to the help afforded.

Juvenal.—Thirteen Satires of JUVENAL. With a Commentary. By JOHN E. B. MAYOR, M.A., Fellow of St. John's College, Cambridge. Second Edition, enlarged. Part I. Crown 8vo. sewed. \$1.25.

Juvenal—continued.

Besides the author's own, there are various other notes, for which the author is indebted to Professors Munro and Conington. All the citations have been taken anew from the original authors. "A painstaking and critical edition."—SPECTATOR. "For really ripe scholarship, extensive acquaintance with Latin literature, and familiar knowledge of continental criticism, ancient and modern, it is unsurpassed among English editions."—EDINBURGH REVIEW.

Marshall.—A TABLE OF IRREGULAR GREEK VERBS, classified according to the arrangement of Curtius' Greek Grammar. By J. M. MARSHALL, M.A., Fellow and late Lecturer of Brasenose College, Oxford; one of the Masters in Clifton College. 8vo. cloth. New Edition. 40 Cents.

The system of this table has been borrowed from the excellent Greek Grammar of Dr. Curtius.

Mayor (John E. B.)—FIRST GREEK READER. Edited after KARL HALM, with Corrections and large Additions by JOHN E. B. MAYOR, M.A., Fellow and Classical Lecturer of St. John's College, Cambridge. Second and Cheaper Edition. Fcap. 8vo. \$1.50.

A selection of short passages, serving to illustrate especially the Greek Accidence. A good deal of syntax is incidentally taught, and Madvig and other books are cited, for the use of masters: but no learner is expected to know more of syntax than is contained in the Notes and Vocabulary. A preface "To the Reader," not only explains the aim and method of the volume, but also deals with classical instruction generally. The extracts are uniformly in the Attic dialect. This book may be used in connexion with Mayor's "Greek for Beginners." "After a careful examination we are inclined to consider this volume unrivalled in the hold which its pithy sentences are likely to take on the memory, and for the amount of true scholarship embodied in the annotations."—EDUCATIONAL TIMES.

Mayor (Joseph B.)—GREEK FOR BEGINNERS. By the Rev. J. B. MAYOR, M.A., Professor of Classical Literature in King's College, London. Complete in one vol., fcap. 8vo. cloth, \$1'50.

The distinctive method of this book consists in building up a boy's knowledge of Greek upon the foundation of his knowledge of English and Latin, instead of trusting everything to the unassisted memory. Greek words have been used in the earlier part of the book except such as have connections either in English or Latin. Each step leads naturally on to its successor; grammatical forms and rules are at once applied in a series of graduated exercises, accompanied by ample vocabularies. Thus the book serves as Grammar, Exercise book, and Vocabulary. The ordinary ten declensions are reduced to three, which correspond to the first three in Latin; and the system of stems is adopted. A general Vocabulary, and Index of Greek words, completes the work. "We know of no book of the same scope so complete in itself, or so well calculated to make the study of Greek interesting at the very commencement."—STANDARD.

Peile (John, M.A.)—AN INTRODUCTION TO GREEK AND LATIN ETYMOLOGY. By JOHN PEILE, M.A., Fellow and Assistant Tutor of Christ's College, Cambridge, formerly Teacher of Sanskrit in the University of Cambridge. New and Revised Edition. Crown 8vo. \$3'50.

These Philological Lectures are the result of Notes made during the author's reading for several years. These Notes were put into the shape of lectures, delivered at Christ's College, as one set in the "Intercollegiate" list. They are now printed with some additions and modifications. "The book may be accepted as a very valuable contribution to the science of language."—SATURDAY REVIEW.

Plato.—THE REPUBLIC OF PLATO. Translated into English, with an Analysis and Notes, by J. LL. DAVIES, M.A., and D. J. VAUGHAN, M.A. Third Edition, with Vignette Portraits of Plato and Socrates, engraved by JEENS from an Antique Gem. 18mo. \$1.25.

An introductory notice supplies some account of the life of Plato, and the translation is preceded by an elaborate analysis. "The translators have," in the judgment of the SATURDAY REVIEW, "produced a book which any reader, whether acquainted with the original or not, can peruse with pleasure as well as profit."

Plautus (Ramsay).—THE MOSTELLARIA OF PLAUTUS. With Notes Critical and Explanatory, Prolegomena, and Excursus. By WILLIAM RAMSAY, M.A., formerly Professor of Humanity in the University of Glasgow. Edited by Professor GEORGE G. RAMSAY, M.A., of the University of Glasgow. 8vo. \$5.

"The fruits of that exhaustive research and that ripe and well-digested scholarship which its author brought to bear upon everything that he undertook are visible throughout it. It is furnished with a complete apparatus of prolegomena, notes, and excursus; and for the use of veteran scholars it probably leaves nothing to be desired."—PALL MALL GAZETTE.

Potts (Alex. W., M.A.)—HINTS TOWARDS LATIN PROSE COMPOSITION. By ALEX. W. POTTS, M.A., late Fellow of St. John's College, Cambridge; Assistant Master in Rugby School; and Head Master of the Fettes College, Edinburgh. New Edition, enlarged. Extra fcap. 8vo. cloth. \$1.

An attempt is here made to give students, after they have mastered ordinary syntactical rules, some idea of the characteristics of Latin Prose and the means to be employed to reproduce them. Some notion of the treatment of the subject may be gathered from the 'Contents.' CHAP. I.—Characteristics of Classical Latin, Hints on turning English into Latin;

ATHENÆUM, "being at once compact, complete, and correct, as well as neatly printed and elegant in style."

THE AGRICOLA and GERMANIA may be had separately, price 75 Cents each.

THE AGRICOLA AND GERMANIA. Translated into English by A. J. CHURCH, M.A., and W. J. BRODRIBB, M.A. With Maps and Notes. Extra fcap. 8vo. \$1.

The translators have sought to produce such a version as may satisfy scholars who demand a faithful rendering of the original, and English readers who are offended by the baldness and frigidity which commonly disfigure translations. The treatises are accompanied by introductions, notes, maps, and a chronological summary. The ATHENÆUM says of this work that it is "a version at once readable and exact, which may be perused with pleasure by all, and consulted with advantage by the classical student."

Theophrastus.—THE CHARACTERS OF THEOPHRASTUS. An English Translation from a Revised Text. With Introduction and Notes. By R. C. JEBB, M.A., Public Orator in the University of Cambridge. Extra fcap. 8vo. \$2.

The first object of this book is to make these lively pictures of old Greek manners better known to English readers. But as the Editor and Translator has been at considerable pains to procure a trustworthy text, and has recorded the results of his critical labours in an Introduction, Notes, and Appendices, it is hoped that the work will prove of value even to the scholar. "We must not omit to give due honour to Mr. Jebb's translation, which is as good as translation can be . . . Not less commendable are the execution of the Notes and the critical handling of the Text."—SPECTATOR.

The SATURDAY REVIEW speaks of it as "a very handy and scholarly edition of a work which till now has been beset with hindrances and difficulties, but which Mr. Jebb's critical skill and judgment have at 'ced within the grasp and comprehension of ordinary readers."

Thring.—Works by the Rev. E. THRING, M.A., Head Master of Uppingham School.

A LATIN GRADUAL. A First Latin Construing Book for Beginners. New Edition, enlarged, with Coloured Sentence Maps. Fcap. 8vo. \$1.25.

The Head Master of Uppingham has here sought to supply by easy steps a knowledge of grammar, combined with a good Vocabulary. Passages have been selected from the best Latin authors in prose and verse. These passages are gradually built up in their grammatical structure, and finally printed in full. A short practical manual of common mood constructions, with their English equivalents, forms a second part. To the New Edition a circle of grammatical constructions with a glossary has been added; as also some coloured Sentence Maps, by means of which the different parts of a sentence can easily be distinguished, and the practice of dissecting phrases carried out with the greatest benefit to the student.

A MANUAL OF MOOD CONSTRUCTIONS. Fcap. 8vo. 75 Cents.

Treats of the ordinary mood constructions, as found in the Latin, Greek, and English languages. The EDUCATIONAL TIMES thinks it "very well suited to young students."

A CONSTRUING BOOK. Fcap. 8vo. 75 Cents.

Thucydides.—THE SICILIAN EXPEDITION. Being Books VI. and VII. of Thucydides, with Notes. A New Edition, revised and enlarged, with a Map. By the Rev. PERCIVAL FROST, M.A., late Fellow of St. John's College, Cambridge. Fcap. 8vo. \$1.50.

This edition is mainly a grammatical one. Attention is called to the force of compound verbs, and the exact meaning of the various tenses employed. "The notes are excellent of their kind. Mr. Frost seldom passes over a difficulty, and what he says is always to the point."—EDUCATIONAL TIMES.

Virgil.—THE WORKS OF VIRGIL RENDERED INTO ENGLISH PROSE, with Notes, Introductions, Running Analysis, and an Index, by JAMES LONSDALE, M.A. and SAMUEL LEE, M.A. Second Edition. Globe 8vo. \$1.50; gilt edges, \$2.

The original has been faithfully rendered, and paraphrase altogether avoided. At the same time, the translators have endeavoured to adapt the book to the use of the English reader. Some amount of rhythm in the structure of the sentence has been generally maintained; and, when in the Latin the sound of the words is an echo to the sense (as so frequently happens in Virgil), an attempt has been made to produce the same result in English. The general introduction contains whatever is known of the poet's life, an estimate of his genius, an account of the principal editions and translations of his works, and a brief view of the influence he has had on modern poets; special introductory essays are prefixed to the "Eclogues," "Georgics," and "Æneid." The text is divided into sections, each of which is headed by a concise analysis of the subject; the index contains references to all the characters and events of any importance. "A more complete edition of Virgil in English it is scarcely possible to conceive than the scholarly work before us."—GLOBE.

Wright.—Works by J. WRIGHT, M.A., late Head Master of Sutton Coldfield School.

HELLENICA ; OR, A HISTORY OF GREECE IN GREEK, as related by Diodorus and Thucydides; being a First Greek Reading Book, with explanatory Notes, Critical and Historical. Third Edition, with a Vocabulary. 12mo. \$1.

In the last twenty chapters of this volume, Thucydides sketches the rise and progress of the Athenian Empire in so clear a style and in such simple language, that the editor has doubts whether any easier or more instructive passages can be selected for the use of the pupil who is commencing Greek. This book includes a chronological table of the events recorded. The GUARDIAN speaks of the work as "a good plan well executed."

Wright—continued.

A HELP TO LATIN GRAMMAR ; or, The Form and Use of Words in Latin, with Progressive Exercises. Crown 8vo. \$1.25.

This book is not intended as a rival to any of the excellent Grammars now in use ; but as a help to enable the beginner to understand them.

THE SEVEN KINGS OF ROME. An Easy Narrative, abridged from the First Book of Livy by the omission of Difficult Passages ; being a First Latin Reading Book, with Grammatical Notes. With Vocabulary and Exercises. Fourth Edition. Fcap. 8vo. \$1.50.

This work is intended to supply the pupil with an easy construing book, which may at the same time be made the vehicle for instructing him in the rules of grammar and principles of composition. The notes profess to teach what is commonly taught in grammars. It is conceived that the pupil will learn the rules of construction of the language much more easily from separate examples, which are pointed out to him in the course of his reading, and which he may himself set down in his note-book after some scheme of his own, than from a heap of quotations amassed for him by others. "The Notes are abundant, explicit, and full of such grammatical and other information as boys require."—ATHENÆUM. "This is really," the MORNING POST says, "what its title imports, and we believe that its general introduction into Grammar Schools would not only facilitate the progress of the boys beginning to learn Latin, but also relieve the Masters from a very considerable amount of irksome labour . . . a really valuable addition to our school libraries."

Or, separately,

SEVEN KINGS OF ROME. \$1.

VOCABULARY AND EXERCISES TO "THE SEVEN KINGS."
75 Cents.

FIRST LATIN STEPS ; OR, AN INTRODUCTION BY A SERIES OF EXAMPLES TO THE STUDY OF THE LATIN LANGUAGE. Crown 8vo. \$2.

Wright—continued.

The following points in the plan of the work may be noted:—1. The pupil has to deal with only one construction at a time. 2. This construction is made clear to him by an accumulation of instances. 3. As all the constructions are classified as they occur, the construction in each sentence can be easily referred to its class. 4. As the author thinks the pupil ought to be thoroughly familiarized, by a repetition of instances, with a construction in a foreign language, before he attempts himself to render it in that language, the present volume contains only Latin sentences. 5. The author has added to the Rules on Prosody in the last chapter, a few familiar lines from Ovid's Fasti by way of illustration. In a brief Introduction the author states the rationale of the principal points of Latin Grammar. Copious Notes are appended, to which reference is made in the text. From the clear and rational method adopted in the arrangement of this elementary work, from the simple way in which the various rules are conveyed, and from the abundance of examples given, both teachers and pupils will find it a valuable help to the learning of Latin.

MATHEMATICS.

Airy.—Works by G. B. AIRY, Astronomer Royal :—

ELEMENTARY TREATISE ON PARTIAL DIFFERENTIAL EQUATIONS. Designed for the Use of Students in the Universities. With Diagrams. Crown 8vo. cloth. \$2.

It is hoped that the methods of solution here explained, and the instances exhibited, will be found sufficient for application to nearly all the important problems of Physical Science, which require for their complete investigation the aid of Partial Differential Equations.

ON THE ALGEBRAICAL AND NUMERICAL THEORY OF ERRORS OF OBSERVATIONS AND THE COMBINATION OF OBSERVATIONS. Crown 8vo. cloth. \$2.50.

In order to spare astronomers and observers in natural philosophy the confusion and loss of time which are produced by referring to the ordinary treatises embracing both branches of probabilities (the first relating to chances which can be altered only by the changes of entire units or integral multiples of units in the fundamental conditions of the problem ; the other concerning those chances which have respect to insensible gradations in the value of the element measured), the present tract has been drawn up. It relates only to errors of observation, and to the rules, derivable from the consideration of these errors, for the combination of the results of observations.

Airy (G. B.)—continued.

UNDULATORY THEORY OF OPTICS. Designed for the Use of Students in the University. New Edition. Crown 8vo. cloth. \$2.50.

The undulatory theory of optics is presented to the reader as having the same claims to his attention as the theory of gravitation: namely, that it is certainly true, and that, by mathematical operations of general elegance, it leads to results of great interest. This theory explains with accuracy a vast variety of phenomena of the most complicated kind. The plan of this tract has been to include those phenomena only which admit of calculation, and the investigations are applied only to phenomena which actually have been observed.

ON SOUND AND ATMOSPHERIC VIBRATIONS. With the Mathematical Elements of Music. Designed for the Use of Students of the University. Second Edition, Revised and Enlarged. Crown 8vo. \$3.50.

This volume consists of sections, which again are divided into numbered articles, on the following topics: General recognition of the air as the medium which conveys sound; Properties of the air on which the formation and transmission of sound depend; Theory of undulations as applied to sound, &c.; Investigation of the motion of a wave of air through the atmosphere; Transmission of waves of soniferous vibrations through different gases, solids, and fluids; Experiments on the velocity of sound, &c.; On musical sounds, and the manner of producing them; On the elements of musical harmony and melody, and of simple musical composition; On instrumental music; On the human organs of speech and hearing.

A TREATISE ON MAGNETISM. Designed for the use of Students in the University. Crown 8vo. \$3.

As the laws of Magnetic Force have been experimentally examined with philosophical accuracy, only in its connection with iron and steel, and in

the influences excited by the earth as a whole, the accurate portions of this work are confined to the investigations connected with these metals and the earth. The latter part of the work, however, treats in a more general way of the laws of the connection between Magnetism on the one hand and galvanism and thermo-electricity on the other. The work is divided into Twelve Sections, and each section into numbered articles, each of which states concisely the subject of the following paragraphs.

Airy (Osmund).—A TREATISE ON GEOMETRICAL OPTICS. Adapted for the use of the Higher Classes in Schools. By OSMUND AIRY, B.A., one of the Mathematical Masters in Wellington College. Extra fcap. 8vo. \$1.25.

"This is, I imagine, the first time that any attempt has been made to adapt the subject of Geometrical Optics to the reading of the higher classes in our good schools. That this should be so is the more a matter for remark, since the subject would appear to be peculiarly fitted for such an adaptation. . . . I have endeavoured, as much as possible, to avoid the example of those popular lecturers who explain difficulties by ignoring them. But as the nature of my design necessitated brevity, I have omitted entirely one or two portions of the subject which I considered unnecessary to a clear understanding of the rest, and which appear to me better learnt at a more advanced stage."—AUTHOR'S PREFACE. *"This book," the ATHENÆUM says, "is carefully and lucidly written, and rendered as simple as possible by the use in all cases of the most elementary form of investigation."*

Bayma.—THE ELEMENTS OF MOLECULAR MECHANICS. By JOSEPH BAYMA, S.J., Professor of Philosophy, Stonyhurst College. Demy 8vo. cloth. \$3.75.

Of the twelve Books into which the present treatise is divided, the first and second give the demonstration of the principles which bear directly on the constitution and the properties of matter. The next three books contain a series of theorems and of problems on the laws of motion of elementary substances. In the sixth and seventh, the mechanical constitution of molecules is investigated and determined: and by it the general properties of bodies are explained. The eighth book treats of luminiferous æther. The

ninth explains some special properties of bodies. The tenth and eleventh contain a radical and lengthy investigation of chemical principles and relations, which may lead to practical results of high importance. The twelfth and last book treats of molecular masses, distances, and powers.

Beasley.—AN ELEMENTARY TREATISE ON PLANE TRIGONOMETRY. With Examples. By R. D. BEASLEY, M.A., Head Master of Grantham Grammar School. New Edition, revised and enlarged. Crown 8vo. cloth. \$1.50.

This treatise is specially intended for use in schools. The choice of matter has been chiefly guided by the requirements of the three days' examination at Cambridge. About four hundred examples have been added to this edition, mainly collected from the Examination Papers of the last ten years.

Blackburn (Hugh).—ELEMENTS OF PLANE TRIGONOMETRY, for the use of the Junior Class of Mathematics in the University of Glasgow. By HUGH BLACKBURN, M.A., Professor of Mathematics in the University of Glasgow. Globe 8vo. 75 Cents.

The author having felt the want of a short treatise to be used as a Text-Book after the Sixth Book of Euclid had been learned and some knowledge of Algebra acquired, which should contain satisfactory demonstrations of the propositions to be used in teaching Junior Students the solution of Triangles, and should at the same time lay a solid foundation for the study of Analytical Trigonometry, thinking that others may have felt the same want, has attempted to supply it by the publication of this little work.

Boole.—Works by G. BOOLE, D.C.L., F.R.S., Professor of Mathematics in the Queen's University, Ireland.

A TREATISE ON DIFFERENTIAL EQUATIONS. New and Revised Edition. Edited by I. TODHUNTER. Crown 8vo. cloth.
[In the press.]

Professor Boole has endeavoured in this treatise to convey as complete an account of the present state of knowledge on the subject of Differential Equations.

tions, as was consistent with the idea of a work intended, primarily, for elementary instruction. The earlier sections of each chapter contain that kind of matter which has usually been thought suitable for the beginner, while the latter ones are devoted either to an account of recent discovery, or the discussion of such deeper questions of principle as are likely to present themselves to the reflective student in connection with the methods and processes of his previous course. "A treatise incomparably superior to any other elementary book on the same subject with which we are acquainted."—PHILOSOPHICAL MAGAZINE.

A TREATISE ON DIFFERENTIAL EQUATIONS. Supplementary Volume. Edited by I. TODHUNTER. Crown 8vo. cloth. \$3.50.

This volume contains all that Professor Boole wrote for the purpose of enlarging his treatise on Differential Equations.

THE CALCULUS OF FINITE DIFFERENCES. Crown 8vo. cloth. \$3.50.

In this exposition of the Calculus of Finite Differences, particular attention has been paid to the connection of its methods with those of the Differential Calculus—a connection which in some instances involves far more than a merely formal analogy. The work is in some measure designed as a sequel to Professor Boole's Treatise on Differential Equations. "As an original book by one of the first mathematicians of the age, it is out of all comparison with the mere second-hand compilations which have hitherto been alone accessible to the student."—PHILOSOPHICAL MAGAZINE.

Cambridge Senate-House Problems and Riders,
WITH SOLUTIONS:—

1848-1851.—PROBLEMS. By FERRERS and JACKSON. 8vo. cloth. \$6.

1848-1851.—RIDERS. By JAMESON. 8vo. cloth. \$3.

1854.—PROBLEMS AND RIDERS. By WALTON and MACKENZIE. 8vo. cloth. \$4.

1857.—PROBLEMS AND RIDERS. By CAMPION and WALTON. 8vo. cloth. \$3.50.

Cambridge Senate-House Problems—continued.

1860.—PROBLEMS AND RIDERS. By WATSON and ROUTH.
Crown 8vo. cloth. \$3.

1864.—PROBLEMS AND RIDERS. By WALTON and WILKINSON. 8vo. cloth. \$4.

These volumes will be found of great value to Teachers and Students, as indicating the style and range of mathematical study in the University of Cambridge.

CAMBRIDGE COURSE OF ELEMENTARY NATURAL PHILOSOPHY, for the Degree of B.A. Originally compiled by J. C. SNOWBALL, M.A., late Fellow of St. John's College. Fifth Edition, revised and enlarged, and adapted for the Middle-Class Examinations by THOMAS LUND, B.D., Late Fellow and Lecturer of St. John's College, Editor of Wood's Algebra, &c. Crown 8vo. cloth. \$1.75.

This work will be found adapted to the wants, not only of University Students, but also of many others who require a short course of Mechanics and Hydrostatics, and especially of the candidates at our Middle Class Examinations. At the end of each chapter a series of easy questions is added for the exercise of the student.

CAMBRIDGE AND DUBLIN MATHEMATICAL JOURNAL.

The Complete Work, in Nine Vols. 8vo. cloth, \$84.

Only a few copies remain on hand. Among Contributors to this work will be found Sir W. Thomson, Stokes, Adams, Boole, Sir W. R. Hamilton, De Morgan, Cayley, Sylvester, Jellett, and other distinguished mathematicians.

Candler.—HELP TO ARITHMETIC. Designed for the use of Schools. By H. CANDLER, M.A. Mathematical Master of Uppingham School. Extra fcap. 8vo. \$1.

This work is intended as a companion to any text-book that may be in use. "The main difficulties which boys experience in the different rules are skilfully dealt with and removed."—MUSEUM.

Cheyne.—Works by C. H. H. CHEYNE, M.A., F.R.A.S.

AN ELEMENTARY TREATISE ON THE PLANETARY THEORY. With a Collection of Problems. Second Edition. Crown 8vo. cloth. \$2.50.

In this volume, an attempt has been made to produce a treatise on the Planetary theory, which, being elementary in character, should be so far complete as to contain all that is usually required by students in the University of Cambridge. In the New Edition the work has been carefully revised. The stability of the Planetary System has been more fully treated, and an elegant geometrical explanation of the formulæ for the secular variation of the node and inclination has been introduced.

THE EARTH'S MOTION OF ROTATION. Crown 8vo. \$1.50.

The first part of this work consists of an application of the method of the variation of elements to the general problem of rotation. In the second part the general rotation formulæ are applied to the particular case of the earth.

Childe.—THE SINGULAR PROPERTIES OF THE ELLIPSOID AND ASSOCIATED SURFACES OF THE NTH DEGREE. By the Rev. G. F. CHILDE, M.A., Author of "Ray Surfaces," "Related Caustics," &c. 8vo. \$3.25.

The object of this volume is to develop peculiarities in the Ellipsoid; and, further, to establish analogous properties in the unlimited congeneric series of which this remarkable surface is a constituent.

Christie.—A COLLECTION OF ELEMENTARY TEST-QUESTIONS IN PURE AND MIXED MATHEMATICS; with Answers and Appendices on Synthetic Division, and on the Solution of Numerical Equations by Horner's Method. By JAMES R. CHRISTIE, F.R.S.; late First Mathematical Master at the Royal Military Academy, Woolwich. Crown 8vo. cloth. \$3.

This series of Mathematical exercises is collected from those which the author has, from time to time, proposed for solution by his pupils during

a long career at the Royal Military Academy. A student who finds that he is able to solve the larger portion of these exercises, may consider that he is thoroughly well grounded in the elementary principles of pure and mixed Mathematics.

Dalton.—ARITHMETICAL EXAMPLES. Progressively arranged, with Exercises and Examination Papers. By the Rev. T. DALTON, M.A., Assistant Master of Eton College. 18mo. cloth. \$1. *Answers to the Examples are appended.*

Day.—PROPERTIES OF CONIC SECTIONS PROVED GEOMETRICALLY. PART I., THE ELLIPSE, with Problems. By the Rev. H. G. DAY, M.A., Head Master of Sedburgh Grammar School. Crown 8vo. \$1'25.

The object of this book is the introduction of a treatment of Conic Sections which should be simple and natural, and lead by an easy transition to the analytical methods, without departing from the strict geometry of Euclid.

Dodgson.—AN ELEMENTARY TREATISE ON DETERMINANTS, with their Application to Simultaneous Linear Equations and Algebraical Geometry. By CHARLES L. DODGSON, M.A., Student and Mathematical Lecturer of Christ Church, Oxford. Small 4to. cloth. \$3'50.

The object of the author is to present the subject as a continuous chain of argument, separated from all accessories of explanation or illustration. All such explanation and illustration as seemed necessary for a beginner are introduced, either in the form of foot-notes, or, where that would have occupied too much room, of Appendices. "The work," says the EDUCATIONAL TIMES, "forms a valuable addition to the treatises we possess on modern Algebra."

Drew.—GEOMETRICAL TREATISE ON CONIC SECTIONS. By W. H. DREW, M.A., St. John's College, Cambridge. Fourth Edition. Crown 8vo. cloth. \$1'75.

Drew—continued.

In this work the subject of Conic Sections has been placed before the student in such a form that, it is hoped, after mastering the elements of Euclid, he may find it an easy and interesting continuation of his geometrical studies. With a view, also, of rendering the work a complete manual of what is required at the Universities, there have either been embodied into the text or inserted among the examples, every book-work question, problem, and rider, which has been proposed in the Cambridge examinations up to the present time.

SOLUTIONS TO THE PROBLEMS IN DREW'S CONIC SECTIONS. Crown 8vo. cloth. \$1.75.

Earnshaw (S.) — PARTIAL DIFFERENTIAL EQUATIONS. An Essay towards an entirely New Method of Integrating them. By S. EARNSHAW, M.A., St. John's College, Cambridge. Crown 8vo. \$2.50.

The peculiarity of the system expounded in this work is, that in every equation, whatever be the number of original independent variables, the work of integration is at once reduced to the use of one independent variable only. The author's object is merely to render his method thoroughly intelligible. The various steps of the investigation are all obedient to one general principle, and though in some degree novel, are not really difficult, but on the contrary easy when the eye has become accustomed to the novelties of the notation. Many of the results of the integrations are far more general than they were in the shape in which they have appeared in former Treatises, and many Equations will be found in this Essay integrated with ease in finite terms, which were never so integrated before.

Edgar (J. H.) and Pritchard (G. S.)—NOTE-BOOK ON PRACTICAL SOLID OR DESCRIPTIVE GEOMETRY. Containing Problems with help for Solutions. By J. H. EDGAR, M.A., Lecturer on Mechanical Drawing at the Royal School of Mines, and G. S. PRITCHARD, late Master for Descriptive Geometry, Royal Military Academy, Woolwich. Second Edition, revised and enlarged. Globe 8vo. \$1.25.

In teaching a large class, if the method of lecturing and demonstrating from the black board only is pursued, the more intelligent students have generally to be kept back, from the necessity of frequent repetition, for the sake of the less promising; if the plan of setting problems to each pupil is adopted, the teacher finds a difficulty in giving to each sufficient attention. A judicious combination of both methods is doubtless the best; and it is hoped that this result may be arrived at in some degree by the use of this book, which is simply a collection of examples, with helps for solution, arranged in progressive sections. The new edition has been enlarged by the addition of chapters on the straight line and plane, with explanatory diagrams and exercises, on tangent planes, and on the cases of the spherical triangle.

Ferrers.—AN ELEMENTARY TREATISE ON TRILINEAR CO-ORDINATES, the Method of Reciprocal Polars, and the Theory of Projectors. By the Rev. N. M. FERRERS, M.A., Fellow and Tutor of Gonville and Caius College, Cambridge. Second Edition. Crown 8vo. \$2.

The object of the author in writing on this subject has mainly been to place it on a basis altogether independent of the ordinary Cartesian system, instead of regarding it as only a special form of Abridged Notation. A short chapter on Determinants has been introduced.

Frost.—Works by PERCIVAL FROST, M.A., formerly Fellow of St. John's College, Cambridge; Mathematical Lecturer of King's College.

AN ELEMENTARY TREATISE ON CURVE TRACING. By PERCIVAL FROST, M.A. 8vo. \$6.

The author has written this book under the conviction that the skill and power of the young mathematical student, in order to be thoroughly available afterwards, ought to be developed in all possible directions. The subject which he has chosen presents so many faces, that it would be difficult to find another which, with a very limited extent of reading, combines, to the same extent, so many valuable hints of methods of calculations to be employed hereafter, with so much pleasure in its present

use. In order to understand the work it is not necessary to have much knowledge of what is called Higher Algebra, nor of Algebraical Geometry of a higher kind than that which simply relates to the Conic Sections. From the study of a work like this, it is believed that the student will derive many advantages. Especially he will become skilled in making correct approximations to the values of quantities, which cannot be found exactly, to any degree of accuracy which may be required.

THE FIRST THREE SECTIONS OF NEWTON'S PRINCIPIA.

With Notes and Illustrations. Also a collection of Problems, principally intended as Examples of Newton's Methods. By PERCIVAL FROST, M.A. Second Edition. 8vo. cloth. \$3.50.

The author's principal intention is to explain difficulties which may be encountered by the student on first reading the Principia, and to illustrate the advantages of a careful study of the methods employed by Newton, by showing the extent to which they may be applied in the solution of problems; he has also endeavoured to give assistance to the student who is engaged in the study of the higher branches of mathematics, by representing in a geometrical form several of the processes employed in the Differential and Integral Calculus, and in the analytical investigations of Dynamics.

Frost and Wolstenholme.—A TREATISE ON SOLID GEOMETRY. By PERCIVAL FROST, M.A., and the Rev. J. WOLSTENHOLME, M.A., Fellow and Assistant Tutor of Christ's College. 8vo. cloth. \$5.50.

The authors have endeavoured to present before students as comprehensive a view of the subject as possible. Intending to make the subject accessible, at least in the earlier portion, to all classes of students, they have endeavoured to explain completely all the processes which are most useful in dealing with ordinary theorems and problems, thus directing the student to the selection of methods which are best adapted to the exigencies of each problem. In the more difficult portions of the subject, they have considered themselves to be addressing a higher class of students; and they have there tried to lay a good foundation on which to build, if any reader should wish to pursue the science beyond the limits to which the work extends.

Godfray.—Works by HUGH GODFRAY, M.A., Mathematical Lecturer at Pembroke College, Cambridge.

A TREATISE ON ASTRONOMY, for the Use of Colleges and Schools. 8vo. cloth. \$4.50.

This book embraces all those branches of Astronomy which have, from time to time, been recommended by the Cambridge Board of Mathematical Studies: but by far the larger and easier portion, adapted to the first three days of the Examination for Honours, may be read by the more advanced pupils in many of our schools. The author's aim has been to convey clear and distinct ideas of the celestial phenomena. "It is a working book," says the GUARDIAN, "taking Astronomy in its proper place in mathematical sciences. . . . It is a book which is not likely to be got up unintelligently."

AN ELEMENTARY TREATISE ON THE LUNAR THEORY, with a Brief Sketch of the Problem up to the time of Newton. Second Edition, revised. Crown 8vo. cloth. \$2.25.

These pages will, it is hoped, form an introduction to more recondite works. Difficulties have been discussed at considerable length. The selection of the method followed with regard to analytical solutions, which is the same as that of Airy, Herschel, &c. was made on account of its simplicity; it is, moreover, the method which has obtained in the University of Cambridge. "As an elementary treatise and introduction to the subject, we think it may justly claim to supersede all former ones."—LONDON, EDIN. AND DUBLIN PHIL. MAGAZINE.

Hemming.—**AN ELEMENTARY TREATISE ON THE DIFFERENTIAL AND INTEGRAL CALCULUS**, for the Use of Colleges and Schools. By G. W. HEMMING, M.A., Fellow of St. John's College, Cambridge. Second Edition, with Corrections and Additions. 8vo. cloth. \$3.

"There is no book in common use from which so clear and exact a knowledge of the principles of the Calculus can be so readily obtained."—LITERARY GAZETTE.

Jackson.—GEOMETRICAL CONIC SECTIONS. An Elementary Treatise in which the Conic Sections are defined as the Plane Sections of a Cone, and treated by the Method of Projection. By J. STUART JACKSON, M.A., late Fellow of Gonville and Caius College, Cambridge. \$1.75.

This work has been written with a view to give the student the benefit of the Method of Projections as applied to the Ellipse and Hyperbola. When this Method is admitted into the treatment of the Conic Sections, there are many reasons why they should be defined, not with reference to the focus and direction, but according to the original definition from which they have their name as plane sections of a cone. This method is calculated to produce a material simplification in these curves, and to make the proof of their properties more easily understood and remembered. It is also a powerful instrument in the solution of a large class of problems relating to these curves.

Jellet (John H.)—A TREATISE ON THE THEORY OF FRICTION. By JOHN H. JELLET, B.D., Senior Fellow of Trinity College, Dublin; President of the Royal Irish Academy. 8vo. \$4.

The theory of friction is as truly a part of Rational Mechanics as the theory of gravitation. This book is taken up with a special investigation of the laws of friction; and some of the principles contained in it are believed to be here enunciated for the first time. The work consists of eight Chapters as follows:—I. Definitions and Principles. II. Equilibrium with Friction. {III. Extreme Positions of Equilibrium. IV. Movement of a Particle or System of Particles. V. Motion of a Solid Body. VI. Necessary and Possible Equilibrium. VII. Determination of the Actual Value of the Acting Force of Friction. VIII. Miscellaneous Problems—
1. Problem of the Top. 2. Friction Wheels and Locomotives. 3. Questions for Exercise. "The work is one of great research, and will add much to the already great reputation of its author."—SCOTSMAN.

Jones and Cheyne.—ALGEBRAICAL EXERCISES. Progressively arranged. By the Rev. C. A. JONES, M.A., and C. H. CHEYNE, M.A., F.R.A.S., Mathematical Masters of Westminster School. New Edition. 18mo. cloth. 75 Cents.

This little book is intended to meet a difficulty which is probably felt more or less by all engaged in teaching Algebra to beginners. It is, that while new ideas are being acquired, old ones are forgotten. In the belief that constant practice is the only remedy for this, the present series of miscellaneous exercises has been prepared. Their peculiarity consists in this, that though miscellaneous they are yet progressive, and may be used by the pupil almost from the commencement of his studies. The book being intended chiefly for Schools and Junior Students, the higher parts of Algebra have not been included.

Kitchener.—A GEOMETRICAL NOTE-BOOK, containing Easy Problems in Geometrical Drawing preparatory to the Study of Geometry. For the Use of Schools. By F. E. KITCHENER, M.A., Mathematical Master at Rugby. New Edition. 4to. 75 Cents.

It is the object of this book to make some way in overcoming the difficulties of Geometrical conception, before the mind is called to the attack of Geometrical theorems. A few simple methods of construction are given; and space is left on each page, in order that the learner may draw in the figures.

Morgan.—A COLLECTION OF PROBLEMS AND EXAMPLES IN MATHEMATICS. With Answers. By H. A. MORGAN, M.A., Sadlerian and Mathematical Lecturer of Jesus College, Cambridge. Crown 8vo. cloth. \$2.

This book contains a number of problems, chiefly elementary, in the Mathematical subjects usually read at Cambridge. They have been selected from the papers set during late years at Jesus College. Very few of them are to be met with in other collections, and by far the larger number are due to some of the most distinguished Mathematicians in the University.

Newton's PRINCIPIA. Edited by Professor Sir W. THOMSON and Professor BLACKBURN. 4to. cloth. \$12.

It is a sufficient guarantee of the excellence of this complete edition of Newton's Principia that it has been printed for and under the care of Professor Sir William Thomson and Professor Blackburn, of Glasgow University. The following notice is prefixed:—"Finding that all the editions of the Principia are now out of print, we have been induced to reprint Newton's last edition [of 1726] without note or comment, only introducing the 'Corrigenda' of the old copy and correcting typographical errors." The book is of a handsome size, with large type, fine thick paper, and cleanly cut figures, and is the only modern edition containing the whole of Newton's great work. "Undoubtedly the finest edition of the text of the 'Principia' which has hitherto appeared."—EDUCATIONAL TIMES.

Parkinson.—Works by S. PARKINSON, D.D., F.R.S., Fellow and Tutor of St. John's College, Cambridge.

AN ELEMENTARY TREATISE ON MECHANICS. For the Use of the Junior Classes at the University and the Higher Classes in Schools. With a Collection of Examples. Fourth edition, revised. Crown 8vo. cloth. \$3.

In preparing this work the author's object has been to include in it such portions of Theoretical Mechanics as can be conveniently investigated without the use of the Differential Calculus, and so render it suitable as a manual for the junior classes in the University and the higher classes in Schools. With one or two short exceptions, the student is not presumed to require a knowledge of any branches of Mathematics beyond the elements of Algebra, Geometry, and Trigonometry. Several additional propositions have been incorporated in the work for the purpose of rendering it more complete; and the collection of Examples and Problems has been largely increased.

A TREATISE ON OPTICS. Third Edition, revised and enlarged. Crown 8vo. cloth. \$3.50.

A collection of examples and problems has been appended to this work, which are sufficiently numerous and varied in character to afford useful

exercise for the student. For the greater part of them, recourse has been had to the Examination Papers set in the University and the several Colleges during the last twenty years.

Phear.—ELEMENTARY HYDROSTATICS. With Numerous Examples. By J. B. PHEAR, M.A., Fellow and late Assistant Tutor of Clare College, Cambridge. Fourth Edition. Crown 8vo. cloth. \$2.

This edition has been carefully revised throughout, and many new illustrations and examples added, which it is hoped will increase its usefulness to students at the Universities and in Schools. In accordance with suggestions from many engaged in tuition, answers to all the Examples have been given at the end of the book.

Pratt.—A TREATISE ON ATTRACTIONS, LAPLACE'S FUNCTIONS, AND THE FIGURE OF THE EARTH. By JOHN H. PRATT, M.A., Archdeacon of Calcutta, Author of "The Mathematical Principles of Mechanical Philosophy." Fourth Edition. Crown 8vo. cloth. \$2.25.

The author's chief design in this treatise is to give an answer to the question, "Has the Earth acquired its present form from being originally in a fluid state?" This Edition is a complete revision of the former ones.

Puckle.—AN ELEMENTARY TREATISE ON CONIC SECTIONS AND ALGEBRAIC GEOMETRY. With Numerous Examples and Hints for their Solution; especially designed for the Use of Beginners. By G. H. PUCKLE, M.A., Head Master of Windermere College. New Edition, revised and enlarged. Crown 8vo. cloth. \$2.50.

This work is recommended by the Syndicate of the Cambridge Local Examinations, and is the text-book in Harvard University, U.S. The ATHENÆUM says the author "displays an intimate acquaintance with the difficulties likely to be felt, together with a singular aptitude in removing them."

Rawlinson.—ELEMENTARY STATICS, by the Rev. GEORGE RAWLINSON, M.A. Edited by the Rev. EDWARD STURGES, M.A., of Emmanuel College, Cambridge, and late Professor of the Applied Sciences, Elphinstone College, Bombay. Crown 8vo. cloth. \$1.75.

Published under the authority of Her Majesty's Secretary of State for India, for use in the Government Schools and Colleges in India.

Reynolds.—MODERN METHODS IN ELEMENTARY GEOMETRY. By E. M. REYNOLDS, M.A., Mathematical Master in Clifton College. Crown 8vo. \$1.25.

This little book has been constructed on one plan throughout, that of always giving in the simplest possible form the direct proof from the nature of the case. The axioms necessary to this simplicity have been assumed without hesitation, and no scruple has been felt as to the increase of their number, or the acceptance of as many elementary notions as common experience places past all doubt. The book differs most from established teaching in its constructions, and in its early application of Arithmetic to Geometry.

Routh.—AN ELEMENTARY TREATISE ON THE DYNAMICS OF THE SYSTEM OF RIGID BODIES. With Numerous Examples. By EDWARD JOHN ROUTH, M.A., late Fellow and Assistant Tutor of St. Peter's College, Cambridge; Examiner in the University of London. Second Edition, enlarged. Crown 8vo. cloth. \$3.50.

In this edition the author has made several additions to each chapter. He has tried, to make each chapter, as far as possible, complete in itself, so that all that relates to any one part of the subject may be found in the same place. This arrangement will enable every student to select his own order in which to read the subject. The Examples which will be found at the end of each chapter have been chiefly selected from the Examination Papers which have been set in the University and the Colleges in the last few years.

Smith.—Works by the Rev. BARNARD SMITH, M.A., Rector of Glaston, Rutland, late Fellow and Senior Bursar of St. Peter's College, Cambridge.

THE METRIC SYSTEM OF ARITHMETIC, ITS PRINCIPLES AND APPLICATION, with numerous Examples, written expressly for Standard V. in National Schools. Fourth Edition. 18mo. cloth sewed. 10 Cents.

In the New Code of Regulations issued by the Council of Education it is stated "that in all schools children in Standards V. and VI. should know the principles of the Metric System, and be able to explain the advantages to be gained from uniformity in the method of forming multiples and sub-multiples of the unit." In this little book, Mr. Smith clearly and simply explains the principle of the Metric System, and in considerable detail expounds the French system, and its relation to the ordinary English method, taking the pupil on as far as Compound Division. The book contains numerous Examples, and two wood-cuts illustrating the Metric Tables of Surface and Solidity. Answers to the Examples are appended.

A CHART OF THE METRIC SYSTEM, on a Sheet, size 42 in. by 34 in. on Roller, mounted and varnished, price \$1.50. Third Edition.

By the New Educational Code it is ordained that a Chart of the Metric System be conspicuously hung up on the walls of every school under Government inspection. The publishers believe that the present Chart will be found to answer all the requirements of the Code, and afford a full and perfectly intelligible view of the principles of the Metric System. The principle of the system is clearly stated and illustrated by examples; the Method of Forming the Tables is set forth; Tables follow, clearly showing the English equivalent of the French measures of—1. Length; 2. Surface; 3. Solidity; 4. Weight; 5. Capacity. At the bottom of the Chart is drawn a full-length Metric Measure, subdivided distinctly and intelligibly into Decimetres, Centimetres, and Millimetres. "We do not remember that ever we have seen teaching by a chart more happily carried out."—SCHOOL BOARD CHRONICLE.

Also a Small Chart on a Card, price 5 Cents.

Barnard Smith—*continued.*

AN EASY METHOD OF TEACHING ARITHMETIC IN NATIONAL AND ELEMENTARY SCHOOLS.

This book will be accompanied by diagrams for the walls of school-rooms, which will, it is hoped, readily explain Decimal Notation, &c., and make the acquisition of the Metric System by children an easy task. The book will also be accompanied by a very large number of Examples and Examination Papers. [Nearly ready.

THE METRIC ARITHMETIC.

This book will go thoroughly into the principles of the System, introducing the money tables of the various countries which have adopted it, and containing a very large number of Examples and Examination Papers. [Nearly ready.

Smith (J. Brook).—**ARITHMETIC IN THEORY AND PRACTICE.** By J. BROOK-SMITH, M.A., LL.B., St. John's College, Cambridge; Barrister-at-Law; one of the Masters of Cheltenham College. Crown 8vo. \$2.

Writers on Arithmetic at the present day feel the necessity of explaining the principles on which the rules of the subject are based, but few as yet feel the necessity of making these explanations strict and complete. If the science of Arithmetic is to be made an effective instrument in developing and strengthening the mental powers, it ought to be worked out rationally and conclusively; and in this work the author has endeavoured to reason out in a clear and accurate manner the leading propositions of the science, and to illustrate and apply those propositions in practice. In the practical part of the subject he has advanced somewhat beyond the majority of preceding writers; particularly in Division, in Greatest Common Measure, in Cube Root, in the Chapters on Decimal Money and the Metric System, and more especially in the application of Decimals to Percentages and cognate subjects. Copious examples, original and selected, are given. "This strikes us as a valuable Manual of Arithmetic of the Scientific kind. Indeed, this really appears to us the best we have seen."—**LITERARY CHURCHMAN.** "This is an essentially practical book,

providing very definite help to candidates for almost every kind of competitive examination."—BRITISH QUARTERLY.

Snowball.—THE ELEMENTS OF PLANE AND SPHERICAL TRIGONOMETRY; with the Construction and Use of Tables of Logarithms. By J. C. SNOWBALL, M.A. Tenth Edition. Crown 8vo. cloth. \$2.

In preparing the present edition for the press, the text has been subjected to a careful revision; the proofs of some of the more important propositions have been rendered more strict and general; and more than two hundred examples, taken principally from the questions set of late years in the public examinations of the University and of individual Colleges, have been added to the collection of Examples and Problems for practice.

Tait and Steele.—A TREATISE ON DYNAMICS OF A PARTICLE. With numerous Examples. By Professor TAIT and Mr. STEELE. New Edition, enlarged. Crown 8vo. cloth. \$3.50.

In this treatise will be found all the ordinary propositions, connected with the Dynamics of Particles, which can be conveniently deduced without the use of D'Alembert's Principle. Throughout the book will be found a number of illustrative examples introduced in the text, and for the most part completely worked out; others with occasional solutions or hints to assist the student are appended to each chapter. For by far the greater portion of these, the Cambridge Senate-House and College Examination Papers have been applied to. In the new edition numerous trivial errors, and a few of a more serious character, have been corrected, while many new examples have been added.

Taylor.—GEOMETRICAL CONICS; including Anharmonic Ratio and Projection, with numerous Examples. By C. TAYLOR, B.A., Scholar of St. John's College, Cambridge. Crown 8vo. cloth. \$2.50.

This work contains elementary proofs of the principal properties of Conic Sections, together with chapters on Projection and Anharmonic Ratio.

Tebay.—ELEMENTARY MENSURATION FOR SCHOOLS.

With numerous Examples. By SEPTIMUS TEBAY, B.A., Head Master of Queen Elizabeth's Grammar School, Rivington. Extra fcap. 8vo. \$1.25.

The object of the present work is to enable boys to acquire a moderate knowledge of Mensuration in a reasonable time. All difficult and useless matter has been avoided. The examples for the most part are easy, and the rules are concise. "A very compact useful manual."—SPECTATOR.

WORKS

By I. TODHUNTER, M.A., F.R.S.,

Of St. John's College, Cambridge.

"They are all good, and each volume adds to the value of the rest."—
FREEMAN. "*Perspicuous language, vigorous investigations, scrutiny of difficulties, and methodical treatment, characterise Mr. Todhunter's works.*"
—CIVIL ENGINEER.

THE ELEMENTS OF EUCLID. For the Use of Colleges and Schools. New Edition. 18mo. cloth. \$1.25.

No method of overcoming the difficulties experienced by young students of Euclid appears to be so useful as that of breaking up the demonstrations into their constituent parts; a plan strongly recommended by Professor De Morgan. In the present Edition each distinct assertion in the argument begins a new line; and at the ends of the lines are placed the necessary references to the preceding principles on which the assertions depend. The longer propositions are distributed into subordinate parts, which are distinguished by breaks at the beginning of the lines. Notes, Appendix, and a collection of Exercises are added.

MENSURATION FOR BEGINNERS. With numerous Examples. New Edition. 18mo. cloth. \$1.25.

The subjects included in the present work are those which have usually found a place in Elementary Treatises on Mensuration. The mode of treatment has been determined by the fact that the work is intended for the use of beginners. Accordingly it is divided into short independent chapters, which are followed by appropriate examples. A knowledge of the elements of Arithmetic is all that is assumed; and in connection with most of the Rules of Mensuration it has been found practicable to give such explana-

tions and illustrations as will supply the place of formal mathematical demonstrations, which would have been unsuitable to the character of the work. "For simplicity and clearness of arrangement it is unsurpassed by any text-book on the subject which has come under our notice."—
EDUCATIONAL TIMES.

ALGEBRA FOR BEGINNERS. With numerous Examples. New Edition. 18mo. cloth. \$1.25.

Great pains have been taken to render this work intelligible to young students, by the use of simple language and by copious explanations. In determining the subjects to be included and the space to be assigned to each, the author has been guided by the papers given at the various examinations in elementary Algebra which are now carried on in this country. The book may be said to consist of three parts. The first part contains the elementary operations in integral and fractional expressions; the second the solution of equations and problems; the third treats of various subjects which are introduced but rarely into examination papers, and are more briefly discussed. Provision has at the same time been made for the introduction of easy equations and problems at an early stage—for those who prefer such a course.

KEY TO ALGEBRA FOR BEGINNERS. Crown 8vo. cloth. \$2.25.

TRIGONOMETRY FOR BEGINNERS. With numerous Examples. New Edition. 18mo. cloth. \$1.

Intended to serve as an introduction to the larger treatise on Plane Trigonometry, published by the author. The same plan has been adopted as in the Algebra for Beginners: the subject is discussed in short chapters, and a collection of examples is attached to each chapter. The first fourteen chapters present the geometrical part of Plane Trigonometry; and contain all that is necessary for practical purposes. The range of matter included is such as seems required by the various examinations in elementary Trigonometry which are now carried on in the country. Answers are appended.

Todhunter (I.)—continued.**MECHANICS FOR BEGINNERS.** With numerous Examples.

Second Edition. 18mo. cloth. \$1.50.

Intended as a companion to the two preceding books. The work forms an elementary treatise on demonstrative mechanics. A knowledge of the elements at least of the theory of the subject is extremely valuable even for those who are mainly concerned with practical results. The author has accordingly endeavoured to provide a suitable introduction to the study of applied as well as of theoretical mechanics. The work consists of two parts, namely, Statics and Dynamics. It will be found to contain all that is usually comprised in elementary treatises on Mechanics, together with some additions.

ALGEBRA. For the Use of Colleges and Schools. Fifth Edition.

Crown 8vo. cloth. \$2.25.

This work contains all the propositions which are usually included in elementary treatises on Algebra, and a large number of Examples for Exercise. The author has sought to render the work easily intelligible to students, without impairing the accuracy of the demonstrations, or contracting the limits of the subject. The Examples, about Sixteen hundred and fifty in number, have been selected with a view to illustrate every part of the subject. Each chapter is complete in itself; and the work will be found peculiarly adapted to the wants of students who are without the aid of a teacher. The Answers to the Examples, with hints for the solution of some in which assistance may be needed, are given at the end of the book. In the present edition two New Chapters and Three hundred miscellaneous Examples have been added. The latter are arranged in sets, each set containing ten Examples. "It has merits which unquestionably place it first in the class to which it belongs."—EDUCATOR.

KEY TO ALGEBRA FOR THE USE OF COLLEGES AND SCHOOLS. Crown 8vo. \$3.**AN ELEMENTARY TREATISE ON THE THEORY OF EQUATIONS.** Second Edition, revised. Crown 8vo. cloth. \$2.25.

Todhunter (I.)—continued.

This treatise contains all the propositions which are usually included in elementary treatises on the theory of Equations, together with Examples for exercise. These have been selected from the College and University Examination Papers, and the results have been given when it appeared necessary. In order to exhibit a comprehensive view of the subject, the treatise includes investigations which are not found in all the preceding elementary treatises, and also some investigations which are not to be found in any of them. For the Second Edition the work has been revised, and some additions have been made, the most important being an account of the researches of Professor Sylvester respecting Newton's Rule. "A thoroughly trustworthy, complete, and yet not too elaborate treatise." PHILOSOPHICAL MAGAZINE.

PLANE TRIGONOMETRY. For Schools and Colleges. Fourth Edition. Crown 8vo. cloth. \$1.75.

The design of this work has been to render the subject intelligible to beginners, and at the same time to afford the student the opportunity of obtaining all the information which he will require on this branch of Mathematics. Each chapter is followed by a set of Examples: those which are entitled Miscellaneous Examples, together with a few in some of the other sets, may be advantageously reserved by the student for exercise after he has made some progress in the subject. In the Second Edition the hints for the solution of the Examples have been considerably increased.

A TREATISE ON SPHERICAL TRIGONOMETRY. New Edition, enlarged. Crown 8vo. cloth. \$1.75.

The present work is constructed on the same plan as the treatise on Plane Trigonometry, to which it is intended as a sequel. In the account of Napier's Rules of Circular Parts, an explanation has been given of a method of proof devised by Napier, which seems to have been overlooked by most modern writers on the subject. Considerable labour has been bestowed on the text in order to render it comprehensive and accurate, and the Examples (selected chiefly from College Examination Papers) have all been carefully verified. "For educational purposes this work seems to be superior to any others on the subject."—CRITIC.

Todhunter (I.)—continued.

PLANE CO-ORDINATE GEOMETRY, as applied to the Straight Line and the Conic Sections. With numerous Examples. Fourth Edition, revised and enlarged. Crown 8vo. cloth. \$2'25.

The author has here endeavoured to exhibit the subject in a simple manner for the benefit of beginners, and at the same time to include in one volume all that students usually require. In addition, therefore, to the propositions which have always appeared in such treatises, he has introduced the methods of abridged notation, which are of more recent origin; these methods, which are of a less elementary character than the rest of the work, are placed in separate chapters, and may be omitted by the student at first.

A TREATISE ON THE DIFFERENTIAL CALCULUS. With numerous Examples. Fifth Edition. Crown 8vo. cloth. \$3'50.

The author has endeavoured in the present work to exhibit a comprehensive view of the Differential Calculus on the method of limits. In the more elementary portions he has entered into considerable detail in the explanations, with the hope that a reader who is without the assistance of a tutor may be enabled to acquire a competent acquaintance with the subject. The method adopted is that of Differential Coefficients. To the different chapters are appended examples sufficiently numerous to render another book unnecessary; these examples being mostly selected from College Examination Papers. "It has already taken its place as the text-book on that subject."—PHILOSOPHICAL MAGAZINE.

A TREATISE ON THE INTEGRAL CALCULUS AND ITS APPLICATIONS. With numerous Examples. Third Edition, revised and enlarged. Crown 8vo. cloth. \$3'50.

This is designed as a work at once elementary and complete, adapted for the use of beginners, and sufficient for the wants of advanced students. In the selection of the propositions, and in the mode of establishing them, it has been sought to exhibit the principles clearly, and to illustrate all their most important results. The process of summation has been repeatedly brought forward, with the view of securing the attention of

Todhunter (I.)—continued.

the student to the notions which form the true foundation of the Calculus itself, as well as of its most valuable applications. Every attempt has been made to explain those difficulties which usually perplex beginners, especially with reference to the limits of integrations. A new method has been adopted in regard to the transformation of multiple integrals. The last chapter deals with the Calculus of Variations. A large collection of exercises, selected from College Examination Papers, has been appended to the several chapters.

EXAMPLES OF ANALYTICAL GEOMETRY OF THREE DIMENSIONS. Second Edition, revised. Crown 8vo. cloth. \$1.50.

A TREATISE ON ANALYTICAL STATICS. With numerous Examples. Third Edition, revised and enlarged. Crown 8vo. cloth. \$3.50.

In this work on statics (treating of the laws of the equilibrium of bodies) will be found all the propositions which usually appear in treatises on Theoretical Statics. To the different chapters examples are appended, which have been principally selected from University Examination Papers. In the Third Edition many additions have been made, in order to illustrate the application of the principles of the subject to the solution of problems.

A HISTORY OF THE MATHEMATICAL THEORY OF PROBABILITY, from the time of Pascal to that of Laplace. 8vo. \$8.

The subject of this volume has high claims to consideration on account of the subtle problems which it involves, the valuable contributions to analysis which it has produced, its important practical applications, and the eminence of those who have cultivated it. The subject claims all the interest which illustrious names can confer: nearly every great mathematician within the range of a century and a half comes up in the course of the history. The present work, though principally a history, may claim the title of a comprehensive treatise on the Theory of Probability, for it assumes in the reader only so much knowledge as can be gained from an elementary

Todhunter (I.)—continued.

book on *Algebra*, and introduces him to almost every process and every species of problem which the literature of the subject can furnish. The author has been careful to reproduce the essential elements of the original works which he has analysed, and to corroborate his statements by exact quotations from the originals, in the languages in which they were published.

RESEARCHES IN THE CALCULUS OF VARIATIONS, principally on the Theory of Discontinuous Solutions: an Essay to which the Adams Prize was awarded in the University of Cambridge in 1871. 8vo. \$3.50.

The subject of this Essay was prescribed in the following terms by the Examiners:—"A determination of the circumstances under which discontinuity of any kind presents itself in the solution of a problem of maximum or minimum in the Calculus of Variations, and applications to particular instances. It is expected that the discussion of the instances should be exemplified as far as possible geometrically, and that attention be especially directed to cases of real or supposed failure of the Calculus." The Essay, then, is mainly devoted to the consideration of discontinuous solutions, but incidentally various other questions in the Calculus of Variations are examined and elucidated. The author hopes that he has definitely contributed to the extension and improvement of our knowledge of this refined department of analysis.

Wilson (J. M.)—ELEMENTARY GEOMETRY. Angles, Parallels, Triangles, Equivalent Figures, the Circle, and Proportion. By J. M. WILSON, M.A., late Fellow of St. John's College, Cambridge, and Mathematical Master of Rugby School. Second Edition: Extra fcap. 8vo. \$1.25.

The distinctive features of this work are intended to be the following. The classification of Theorems according to their subjects; the separation of Theorems and Problems; the use of hypothetical constructions; the

adoption of independent proofs where they are possible and simple ; the introduction of the terms locus, projection, &c. ; the importance given to the notion of direction as the property of a straight line ; the intermixing of exercises, classified according to the methods adopted for their solution ; the diminution of the number of Theorems ; the compression of proofs, especially in the later parts of the book ; the tacit, instead of the explicit, reference to axioms ; and the treatment of parallels. "The methods employed have the great merit of suggesting a ready application to the solution of fresh problems."—GUARDIAN.

ELEMENTARY GEOMETRY. PART II. (separately). The Circle and Proportion. By J. M. WILSON, M.A. Extra fcap. 8vo. 75 Cents.

SOLID GEOMETRY AND CONIC SECTIONS. With Appendices on Transversals and Harmonic Division. For the use of Schools. By J. M. WILSON, M.A. Extra fcap. 8vo. \$1.25.

This work is an endeavour to introduce into schools some portions of Solid Geometry which are now very little read in England. The first twenty-one Propositions of Euclid's Eleventh Book are usually all the Solid Geometry that a boy reads till he meets with the subject again in the course of his analytical studies. And this is a matter of regret, because this part of Geometry is specially valuable and attractive. In it the attention of the student is strongly called to the subject matter of the reasoning ; the geometrical imagination is exercised ; the methods employed in it are more ingenious than those in Plane Geometry, and have greater difficulties to meet ; and the applications of it in practice are more varied.

Wilson (W. P.)—A TREATISE ON DYNAMICS. By W. P. WILSON, M.A., Fellow of St. John's College, Cambridge, and Professor of Mathematics in Queen's College, Belfast. 8vo. \$3.

"This treatise supplies a great educational need."—EDUCATIONAL TIMES.

Wolstenholme.—A BOOK OF MATHEMATICAL PROBLEMS, on Subjects included in the Cambridge Course. By JOSEPH WOLSTENHOLME, Fellow of Christ's College, sometime Fellow of St. John's College, and lately Lecturer in Mathematics at Christ's College. Crown 8vo. cloth. \$3.

CONTENTS:—*Geometry (Euclid)—Algebra—Plane Trigonometry—Geometrical Conic Sections—Analytical Conic Sections—Theory of Equations—Differential Calculus—Integral Calculus—Solid Geometry—Statics—Elementary Dynamics—Newton—Dynamics of a Point—Dynamics of a Rigid Body—Hydrostatics—Geometrical Optics—Spherical Trigonometry and Plane Astronomy.* “*Judicious, symmetrical, and well arranged.*”—GUARDIAN.

SCIENCE.

ELEMENTARY CLASS-BOOKS.

THE importance of Science as an element of sound education is now generally acknowledged ; and accordingly it is obtaining a prominent place in the ordinary course of school instruction. It is the intention of the Publishers to produce a complete series of Scientific Manuals, affording full and accurate elementary information, conveyed in clear and lucid English. The authors are well known as among the foremost men of their several departments ; and their names form a ready guarantee for the high character of the books. Subjoined is a list of those Manuals that have already appeared, with a short account of each. Others are in active preparation ; and the whole will constitute a standard series specially adapted to the requirements of beginners, whether for private study or for school instruction.

ASTRONOMY, by the Astronomer Royal.

POPULAR ASTRONOMY. With Illustrations. By G. B. AIRY, Astronomer Royal. Seventh and cheaper Edition. 18mo. cloth. \$1.50.

This work consists of six lectures, which are intended "to explain to intelligent persons the principles on which the instruments of an Observatory are constructed (omitting all details, so far as they are merely sub-

Elementary Class-Books—continued.

sidary), and the principles on which the observations made with these instruments are treated for deduction of the distances and weights of the bodies of the Solar System, and of a few stars, omitting all minutie of formulæ, and all troublesome details of calculation." The speciality of this volume is the direct reference of every step to the Observatory, and the full description of the methods and instruments of observation.

ASTRONOMY.

MR. LOCKYER'S ELEMENTARY LESSONS IN ASTRONOMY. With Coloured Diagram of the Spectra of the Sun, Stars, and Nebulæ, and numerous Illustrations. By J. NORMAN LOCKYER, F.R.S. Eighth Thousand. 18mo. \$1.75.

The author has here aimed to give a connected view of the whole subject, and to supply facts, and ideas founded on the facts, to serve as a basis for subsequent study and discussion. The chapters treat of the Stars and Nebulæ; the Sun; the Solar System; Apparent Movements of the Heavenly Bodies; the Measurement of Time; Light; the Telescope and Spectroscope; Apparent Places of the Heavenly Bodies; the Real Distances and Dimensions; Universal Gravitation. The most recent astronomical discoveries are incorporated. Mr. Lockyer's work supplements that of the Astronomer Royal mentioned in the previous article. "The book is full, clear, sound, and worthy of attention, not only as a popular exposition, but as a scientific 'Index.'"—ATHENÆUM. *"The most fascinating of elementary books on the Sciences."*—NONCONFORMIST.

QUESTIONS ON LOCKYER'S ELEMENTARY LESSONS IN ASTRONOMY. For the use of Schools. By JOHN FORBES-ROBERTSON. 18mo. cloth limp. 50 Cents.

PHYSIOLOGY.

PROFESSOR HUXLEY'S LESSONS IN ELEMENTARY PHYSIOLOGY. With numerous Illustrations. By T. H. HUXLEY, F.R.S., Professor of Natural History in the Royal School of Mines. Twentieth Thousand. 18mo. cloth. \$1.50.

Elementary Class-Books—continued.

This book describes and explains, in a series of graduated lessons, the principles of Human Physiology; or the Structure and Functions of the Human Body. The first lesson supplies a general view of the subject. This is followed by sections on the Vascular or Venous System, and the Circulation; the Blood and the Lymph; Respiration; Sources of Loss and of Gain to the Blood; the Function of Alimentation; Motion and Locomotion; Sensations and Sensory Organs; the Organ of Sight; the Coalescence of Sensations with one another and with other States of Consciousness; the Nervous System and Innervation; Histology, or the Minute Structure of the Tissues. A Table of Anatomical and Physiological Constants is appended. The lessons are fully illustrated by numerous engravings. "Pure gold throughout."—GUARDIAN. "Unquestionably the clearest and most complete elementary treatise on this subject that we possess in any language."—WESTMINSTER REVIEW.

QUESTIONS ON HUXLEY'S PHYSIOLOGY FOR SCHOOLS.

By T. ALCOCK, M.D. 18mo. 50 Cents.

These Questions were drawn up as aids to the instruction of a class of young people in Physiology.

BOTANY.

PROFESSOR OLIVER'S LESSONS IN ELEMENTARY BOTANY. With nearly Two Hundred Illustrations. Twelfth Thousand. 18mo. cloth. \$1.50.

This book is designed to teach the Elements of Botany on Professor Henslow's plan of selected Types and by the use of Schedules. The earlier chapters, embracing the elements of Structural and Physiological Botany, introduce us to the methodical study of the Ordinal Types. The concluding chapters are entitled, "How to dry Plants" and "How to describe Plants." A valuable Glossary is appended to the volume. In the preparation of this work free use has been made of the manuscript materials of the late Professor Henslow.

Elementary Class-Books—continued.

CHEMISTRY.

PROFESSOR ROSCOE'S LESSONS IN ELEMENTARY CHEMISTRY, INORGANIC AND ORGANIC. By HENRY E. ROSCOE, F.R.S., Professor of Chemistry in Owens College, Manchester. With numerous Illustrations and Chromo-Litho of the Solar Spectrum, and of the Alkalies and Alkaline Earths, New Edition. Thirty-first Thousand. 18mo. cloth. \$1.50.

It has been the endeavour of the author to arrange the most important facts and principles of Modern Chemistry in a plain but concise and scientific form, suited to the present requirements of elementary instruction. For the purpose of facilitating the attainment of exactitude in the knowledge of the subject, a series of exercises and questions upon the lessons have been added. The metric system of weights and measures, and the centigrade thermometric scale, are used throughout the work. The new Edition, besides new wood-cuts, contains many additions and improvements, and includes the most important of the latest discoveries. "As a standard general text-book it deserves to take a leading place."—SPECTATOR. "We unhesitatingly pronounce it the best of all our elementary treatises on Chemistry."—MEDICAL TIMES.

In ordering, please specify *Macmillan's Edition*.

POLITICAL ECONOMY.

POLITICAL ECONOMY FOR BEGINNERS. By MILLICENT G. FAWCETT. New Edition. 18mo. \$1.

This work has been written mainly with the hope that a short and elementary book might help to make Political Economy a more popular study in boys' and girls' schools. In order to adapt the book especially for school use, questions have been added at the end of each chapter. In the new edition each page has been carefully revised, and at the end of each chapter after the questions a few little puzzles have been added, which will add interest to the book and teach the learner to think for himself. "Clear, compact, and comprehensive."—DAILY NEWS. "The relations of capital and labour have never been more simply or more clearly expounded."—CONTEMPORARY REVIEW.

Elementary Class-Books—continued.

LOGIC.

ELEMENTARY LESSONS IN LOGIC ; Deductive and Inductive, with copious Questions and Examples, and a Vocabulary of Logical Terms. By W. STANLEY JEVONS, M.A., Professor of Logic in Owens College, Manchester. Second Edition. 18mo. \$1.25.

In preparing these Lessons the author has attempted to show that Logic, even in its traditional form, can be made a highly useful subject of study, and a powerful means of mental exercise. With this view he has avoided the use of superfluous technical terms, and has abstained from entering into questions of a purely speculative or metaphysical character. For the puerile illustrations too often found in works on Logic, examples drawn from the distinct objects and ideas treated in the natural and experimental sciences have been generally substituted. At the end of almost every Lesson will be found references to the works in which the student will most profitably continue his reading of the subject treated, so that this little volume may serve as a guide to a more extended course of study. The GUARDIAN thinks "nothing can be better for a school-book," and the ATHENÆUM calls it "a manual alike simple, interesting, and scientific."

PHYSICS.

LESSONS IN ELEMENTARY PHYSICS. By BALFOUR STEWART, F.R.S., Professor of Natural Philosophy in Owens College, Manchester. With numerous Illustrations and Chromoliths of the Spectra of the Sun, Stars, and Nebulæ. Fifth Thousand. 18mo. \$1.50.

A description, in an elementary manner, of the most important of those laws which regulate the phenomena of nature. The active agents, heat, light, electricity, etc., are regarded as varieties of energy, and the work is so arranged that their relation to one another, looked at in this light, and the paramount importance of the laws of energy, are clearly brought out. The volume contains all the necessary illustrations, and a plate representing the Spectra of Sun, Stars, and Nebulæ, forms a frontispiece. The EDUCATIONAL TIMES calls this "the beau ideal of a scientific text-book, clear, accurate, and thorough."

MANUALS FOR STUDENTS.

Flower (W. H.)—AN INTRODUCTION TO THE OSTEOLOGY OF THE MAMMALIA. Being the substance of the Course of Lectures delivered at the Royal College of Surgeons of England in 1870. By W. H. FLOWER, F.R.S., F.R.C.S., Hunterian Professor of Comparative Anatomy and Physiology. With numerous Illustrations. Globe 8vo. \$2.

Although the present work contains the substance of a Course of Lectures, the form has been changed, so as the better to adapt it as a handbook for students. Theoretical views have been almost entirely excluded: and while it is impossible in a scientific treatise to avoid the employment of technical terms, it has been the author's endeavour to use no more than absolutely necessary, and to exercise due care in selecting only those that seem most appropriate, or which have received the sanction of general adoption. With a very few exceptions the illustrations have been drawn expressly for this work from specimens in the Museum of the Royal College of Surgeons.

Hooker (Dr.)—THE STUDENT'S FLORA OF THE BRITISH ISLANDS. By J. D. HOOKER, C.B., F.R.S., M.D., D.C.L., Director of the Royal Gardens, Kew. Globe 8vo. \$3.50.

The object of this work is to supply students and field-botanists with a fuller account of the Plants of the British Islands than the manuals hitherto in use aim at giving. The Ordinal, Generic, and Specific characters have been re-written, and are to a great extent original, and drawn from living or dried specimens, or both. "Cannot fail to perfectly fulfil the purpose for which it is intended."—LAND AND WATER. "Containing the fullest and most accurate manual of the kind that has yet appeared."—PALL MALL GAZETTE.

Oliver (Professor).—FIRST BOOK OF INDIAN BOTANY.

By DANIEL OLIVER, F.R.S., F.L.S., Keeper of the Herbarium and Library of the Royal Gardens, Kew, and Professor of Botany in University College, London. With numerous Illustrations. Extra fcap. 8vo. \$2.50.

This manual is, in substance, the author's "Lessons in Elementary Botany," adapted for use in India. In preparing it he has had in view the want, often felt, of some handy résumé of Indian Botany, which might be serviceable not only to residents of India, but also to any one about to proceed thither, desirous of getting some preliminary idea of the Botany of that country. "It contains a well-digested summary of all essential knowledge pertaining to Indian botany, wrought out in accordance with the best principles of scientific arrangement."—ALLEN'S INDIAN MAIL.

Other volumes of these Manuals will follow.

Ball (R. S., A.M.)—EXPERIMENTAL MECHANICS.

A Course of Lectures delivered at the Royal College of Science for Ireland. By ROBERT STAWELL BALL, A.M., Professor of Applied Mathematics and Mechanics in the Royal College of Science for Ireland (Science and Art Department). Royal 8vo. \$6.

The author's aim has been to create in the mind of the student physical ideas corresponding to theoretical laws, and thus to produce a work which may be regarded either as a supplement or an introduction to manuals of theoretic mechanics. To realize this design, the copious use of experimental illustrations was necessary. The apparatus used in the Lectures, and figured in the volume, has been principally built up from Professor Willis's most admirable system. In the selection of the subjects, the question of practical utility has in many cases been regarded as the one of paramount

importance. The elementary truths of Mechanics are too well known to admit of novelty, but it is believed that the mode of treatment which is adopted is more or less original. This is especially the case in the Lectures relating to friction, to the mechanical powers, to the strength of timber and structures, to the laws of motion, and to the pendulum. The illustrations, drawn from the apparatus, are nearly all original, and are beautifully executed.

Cooke (Josiah P., Jun.)—FIRST PRINCIPLES OF CHEMICAL PHILOSOPHY. By JOSIAH P. COOKE, Jun., Ervine Professor of Chemistry and Mineralogy in Harvard College. Crown 8vo.

The object of the author in this book is to present the philosophy of Chemistry in such a form that it can be made with profit the subject of College recitations, and furnish the teacher with the means of testing the student's faithfulness and ability. With this view the subject has been developed in a logical order, and the principles of the science are taught independently of the experimental evidence on which they rest.

Roscoe (H. E.)—SPECTRUM ANALYSIS. Six Lectures, with Appendices, Engravings, Maps, and Chromolithographs. By H. E. ROSCOE, F.R.S., Professor of Chemistry in Owens College, Manchester. Royal 8vo. \$9.

A Second Edition of these popular Lectures, containing all the most recent discoveries and several additional Illustrations. "In six lectures he has given the history of the discovery and set forth the facts relating to the analysis of light in such a way that any reader of ordinary intelligence and information will be able to understand what 'Spectrum Analysis' is, and what are its claims to rank among the most signal triumphs of science of which even this century can boast."—NON-CONFORMIST. "The illustrations—no unimportant part of a book on such a subject—are marvels of wood-printing, and reflect the clearness which is the distinguishing merit of Mr. Roscoe's explanations."—SATURDAY REVIEW. "The lectures themselves furnish a most ad-

mirable elementary treatise on the subject, whilst by the insertion in appendices to each lecture of extracts from the most important published memoirs, the author has rendered it equally valuable as a text-book for advanced students."—WESTMINSTER REVIEW.

Thorpe (T. E.)—A SERIES OF CHEMICAL PROBLEMS, for use in Colleges and Schools. Adapted for the preparation of Students for the Government, Science, and Society of Arts Examinations. With a Preface by Professor ROSCOE. 18mo. cloth. 50 Cents.

In the Preface Dr. Roscoe says—"My experience has led me to feel more and more strongly that by no method can accuracy in a knowledge of chemistry be more surely secured than by attention to the working of well-selected problems, and Dr. Thorpe's thorough acquaintance with the wants of the student is a sufficient guarantee that this selection has been carefully made. I intend largely to use these questions in my own classes, and I can confidently recommend them to all teachers and students of the science."

Wurtz.—A HISTORY OF CHEMICAL THEORY, from the Age of Lavoisier down to the present time. By AD. WURTZ. Translated by HENRY WATTS, F.R.S. Crown 8vo. \$2.

"The treatment of the subject is admirable, and the translator has evidently done his duty most efficiently."—WESTMINSTER REVIEW.
"The discourse, as a résumé of chemical theory and research, unites singular luminousness and grasp. A few judicious notes are added by the translator."—PALL MALL GAZETTE.

MISCELLANEOUS.

Abbott.—A SHAKESPEARIAN GRAMMAR. An Attempt to illustrate some of the Differences between Elizabethan and Modern English. By the Rev. E. A. ABBOTT, M.A., Head Master of the City of London School. For the Use of Schools. New and Enlarged Edition. Extra fcap. 8vo. \$1.75.

The object of this work is to furnish students of Shakespeare and Bacon with a short systematic account of some points of difference between Elizabethan syntax and our own. A section on Prosody is added, and Notes and Questions. The success which has attended the First and Second Editions of the "SHAKESPEARIAN GRAMMAR," and the demand for a Third Edition within a year of the publication of the First, have encouraged the author to endeavour to make the work somewhat more useful, and to render it, as far as possible, a complete book of reference for all difficulties of Shakespearian syntax or prosody. For this purpose the whole of Shakespeare has been re-read, and an attempt has been made to include within this Edition the explanation of every idiomatic difficulty that comes within the province of a grammar as distinct from a glossary. The great object being to make a useful book of reference for students, and especially for classes in schools, several Plays have been indexed so fully that with the aid of a glossary and historical notes the references will serve for a complete commentary. "A critical inquiry, conducted with great skill and knowledge, and with all the appliances of modern philology. . . . We venture to believe that those who consider themselves most proficient as Shakespearians will find something to learn from its pages."—PALL MALL GAZETTE. "Valuable not only as an aid to the critical study of Shakespeare, but as tending to familiarize the reader with Elizabethan English in general."—ATHENÆUM.

Bates.—A CLASS-BOOK OF GEOGRAPHY. Adapted to the recent Programme of the Royal Geographical Society. By H. W. BATES, Assistant Secretary to the Royal Geographical Society. [In the Press.]

Berners.—FIRST LESSONS ON HEALTH. By J. BERNERS. 18mo.

This little book consists of the notes of a number of simple lessons on sanitary subjects given to a class in a National School, and listened to with great interest and intelligence. They have been made as easy and familiar as possible, and as far as they go may be deemed perfectly trustworthy. One of the author's main attempts has been, to translate the concise and accurate language of science into the colloquial nursery dialect comprehensible to children. The book will be found of the highest value to all who have the training of children, who, for want of knowing what this little book teaches, too often grow up to be unhealthy, defective men and women. The Contents are,—I. Introductory. II. Fresh Air. III. Food and Drink. IV. Warmth. V. Cleanliness. VI. Light. VII. Exercise. VIII. Rest.

Besant.—STUDIES IN EARLY FRENCH POETRY. By WALTER BESANT, M.A. Crown 8vo. \$2.50.

A sort of impression rests on most minds that French literature begins with the "siècle de Louis Quatorze;" any previous literature being for the most part unknown or ignored. Few know anything of the enormous literary activity that began in the thirteenth century, was carried on by Rulebeuf, Marie de France, Gaston de Foix, Thibault de Champagne, and Lorris; was fostered by Charles of Orleans, by Margaret of Valois, by Francis the First; that gave a crowd of versifiers to France, enriched, strengthened, developed, and fixed the French language, and prepared the way for Corneille and for Racine. The present work aims to afford information and direction touching these early efforts of France in poetical literature. "In one moderately sized volume he has contrived to introduce us to the very best, if not to all of the early French poets."—ATHENÆUM. "Industry, the insight of a scholar, and a genuine enthusiasm for his subject, combine to make it of very considerable value."—SPECTATOR.

CAMEOS FROM ENGLISH HISTORY—See YONGE (C. M.).

Delamotte.—A BEGINNER'S DRAWING BOOK. By P. H.

DELAMOTTE, F.S.A. Progressively arranged, with upwards of Fifty Plates. Crown 8vo. Stiff covers. 75 Cents.

This work is intended to give such instruction to Beginners in Drawing, and to place before them copies so easy, that they may not find any obstacle in making the first step. Thenceforward the lessons are gradually progressive. Mechanical improvements too have lent their aid. The whole of the Plates have been engraved by a new process, by means of which a varying depth of tone—up to the present time the distinguishing characteristic of pencil drawing—has been imparted to woodcuts. "We have seen and examined a great many drawing-books, but the one now before us strikes us as being the best of them all."—ILLUSTRATED TIMES. *"A concise, simple, and thoroughly practical work. The letter-press is throughout intelligible and to the point."*—GUARDIAN.

D'Oursy and Feillet.—A FRENCH GRAMMAR AT

SIGHT, on an entirely new method. By A. D'OURSY and A. FEILLET. Especially adapted for Pupils preparing for Examination. Fcap. 8vo. cloth extra. \$1.

The method followed in this volume consists in presenting the grammar as much as possible by synoptical tables, which, striking the eye at once, and following throughout the same order—"used—not used;" "changes—does not change"—are easily remembered. The parsing tables will enable the pupil to parse easily from the beginning. The exercises consist of translations from French into English, and from English into French; and of a number of grammatical questions.

Freeman (Edward A.)—OLD-ENGLISH HISTORY.

By EDWARD A. FREEMAN, D.C.L., late Fellow of Trinity College, Oxford. With Five Coloured Maps. Second Edition. Extra fcap. 8vo. half-bound. \$1.75.

The rapid sale of the first edition and the universal approval with which it has been received, show that the author's convictions have been well

founded, that his views have been widely accepted both by teachers and learners, and that the work is eminently calculated to serve the purpose for which it was intended. Although full of instruction and calculated highly to interest and even fascinate children, it is a work which may be and has been used with profit and pleasure by all. "I have, I hope," the author says, "shown that it is perfectly easy to teach children, from the very first, to distinguish true history alike from legend and from wilful invention, and also to understand the nature of historical authorities and to weigh one statement against another. I have throughout striven to connect the history of England with the general history of civilized Europe, and I have especially tried to make the book serve as an incentive to a more accurate study of historical geography." In the present edition the whole has been carefully revised, and such improvements as suggested themselves have been introduced. "The book indeed is full of instruction and interest to students of all ages, and he must be a well-informed man indeed who will not rise from its perusal with clearer and more accurate ideas of a too much neglected portion of English History."—SPECTATOR.

Hales.—LONGER ENGLISH POEMS, with Notes, Philological and Explanatory, and an Introduction on the Teaching of English. Chiefly for use in Schools. Edited by J. W. HALES, M.A., late Fellow and Assistant Tutor of Christ's College, Cambridge, Lecturer in English Literature and Classical Composition at King's College School, London, &c. &c. Extra fcap. 8vo. \$1'75.

This work has been in preparation for some years, and part of it has been used as a class-book by the Editor. It is intended as an aid to the Critical study of English Literature, and contains one or more of the larger poems, each complete, of prominent English authors, from Spenser to Shelley, including Burns' "Cotters' Saturday Night" and "Twa Dogs." In all cases the original spelling and the text of the best editions have been given; only in one or two poems has it been deemed necessary to make slight omissions and changes, "that the reverence due to boys might be well observed." The Introduction consists of Suggestions on Teaching of English. The latter half of the volume is occupied with copious notes, critical, etymological, and explanatory, calculated to give

the learner much insight into the structure and connection of the English tongue. An Index to the notes is appended.

Helfenstein (James).—A COMPARATIVE GRAMMAR OF THE TEUTONIC LANGUAGES. Being at the same time a Historical Grammar of the English Language, and comprising Gothic, Anglo-Saxon, Early English, Modern English, Icelandic (Old Norse), Danish, Swedish, Old High German, Middle High German, Modern German, Old Saxon, Old Frisian, and Dutch. By JAMES HELFENSTEIN, Ph.D. 8vo. \$5.

This work traces the different stages of development through which the various Teutonic languages have passed, and the laws which have regulated their growth. The reader is thus enabled to study the relation which these languages bear to one another, and to the English language in particular, to which special attention is devoted throughout. In the chapters on Ancient and Middle Teutonic Languages no grammatical form is omitted the knowledge of which is required for the study of ancient literature, whether Gothic or Anglo-Saxon or Early English. To each chapter is prefixed a sketch showing the relation of the Teutonic to the cognate languages, Greek, Latin, and Sanskrit. Those who have mastered the book will be in a position to proceed with intelligence to the more elaborate works of Grimm, Bopp, Pott, Schleicher, and others.

Hole.—A GENEALOGICAL STEMMA OF THE KINGS OF ENGLAND AND FRANCE. By the Rev. C. HOLE. On Sheet. 40 Cents.

The different families are printed in distinguishing colours, thus facilitating reference.

A BRIEF BIOGRAPHICAL DICTIONARY. Compiled and Arranged by CHARLES HOLE, M.A., Trinity College, Cambridge. Second Edition, 18mo. neatly and strongly bound in cloth. \$1.25.

The inquiry is frequently made concerning an eminent man, when did he live, or for what was he celebrated, or what biographies have we about him? Such information is concisely supplied in this Dictionary. It contains

more than 18,000 names. *Extreme care has been bestowed on the verification of the dates, and thus numerous errors current in previous works have been corrected. Its size adapts it for the desk, portmanteau, or pocket. "An invaluable addition to our manuals of reference, and from its moderate price cannot fail to become as popular as it is useful."*—TIMES.

Jephson.—SHAKESPEARE'S "TEMPEST." With Glossarial and Explanatory Notes. By the Rev. J. M. JEPHSON. Second Edition. 18mo. 50 Cents.

It is important to find some substitute for classical study, and it is believed that such a substitute may be found in the Plays of Shakespeare. For this purpose the present edition of the "Tempest" has been prepared. The introduction treats briefly of the value of the study of language, the fable of the play, and other points. The notes are intended to teach the student to analyse every obscure sentence and trace out the logical sequence of the poet's thoughts; to point out the rules of Shakespeare's versification, to explain obsolete words and meanings; and to guide the student's taste by directing his attention to such passages as seem especially worthy of note for their poetical beauty or truth to nature. The text is in the main founded upon that of the first collected edition of Shakespeare's Plays.

M'Cosh (Rev. Principal).—For other Works by the same Author, see PHILOSOPHICAL CATALOGUE.

THE LAWS OF DISCURSIVE THOUGHT. Being a Text-Book of Formal Logic. By JAMES M'COSH, D.D., LL.D. 8vo.

In this treatise the Notion (with the Term and the Relation of Thought to Language,) will be found to occupy a larger relative place than in any logical work written since the time of the famous "Art of Thinking." "We heartily welcome his book as one which is likely to be of great value in Colleges and Schools."—ATHENÆUM.

Morris.—HISTORICAL OUTLINES OF ENGLISH ACCIDENCE, comprising Chapters on the History and Development

of the Language, and on Word-formation. By the Rev. RICHARD MORRIS, LL.D., Member of the Council of the Philol. Soc., Lecturer on English Language and Literature in King's College School, Editor of "Specimens of Early English," &c. &c. Fcap. 8vo. \$1.75.

Dr. Morris has endeavoured to write a work which can be profitably used by students and by the upper forms in our public schools. English Grammar, he believes, without a reference to the older forms, must appear altogether anomalous, inconsistent, and unintelligible. His almost unequalled knowledge of early English Literature renders him peculiarly qualified to write a work of this kind. In the writing of this volume, moreover, he has taken advantage of the researches into our language made by all the most eminent scholars in England, America, and on the Continent. The author shows the place of English among the languages of the world, expounds clearly and with great minuteness "Grimm's Law," gives a brief history of the English language and an account of the various dialects, investigates the history and principles of Phonology, Orthography, Accent, and Etymology, and devotes several chapters to the consideration of the various Parts of Speech, and the final one to Derivation and Word-Formation. "It makes an era in the study of the English tongue."—SATURDAY REVIEW. "He has done his work with a fulness and completeness that leave nothing to be desired."—NON-CONFORMIST. "A genuine and sound book."—ATHENÆUM.

Oppen.—FRENCH READER. For the Use of Colleges and Schools. Containing a graduated Selection from modern Authors in Prose and Verse; and copious Notes, chiefly Etymological. By EDWARD A. OPPEN. Fcap. 8vo. cloth. \$1.50.

This is a Selection from the best modern authors of France. Its distinctive feature consists in its etymological notes, connecting French with the classical and modern languages, including the Celtic. This subject has hitherto been little discussed even by the best-educated teachers.

SHILLING BOOK OF GOLDEN DEEDS. See YONGE (C. M.).

Sonnenschein and Meiklejohn.—THE ENGLISH METHOD OF TEACHING TO READ. By A. SONNENSCHIEIN and J. M. D. MEIKLEJOHN, M.A. Fcap. 8vo. 40 Cents.

COMPRISING :

THE NURSERY BOOK, containing all the Two-Letter Words in the Language. (Also in Large Type on Sheets for School Walls.)

THE FIRST COURSE, consisting of Short Vowels with Single Consonants.

THE SECOND COURSE, with Combinations and Bridges, consisting of Short Vowels with Double Consonants.

THE THIRD AND FOURTH COURSES, consisting of Long Vowels, and all the Double Vowels in the Language.

A Series of Books in which an attempt is made to place the process of learning to read English on a scientific basis. This has been done by separating the perfectly regular parts of the language from the irregular, and by giving the regular parts to the learner in the exact order of their difficulty. The child begins with the smallest possible element, and adds to that element one letter—in only one of its functions—at one time. Thus the sequence is natural and complete. "These are admirable books, because they are constructed on a principle, and that the simplest principle on which it is possible to learn to read English."—SPECTATOR.

Thring.—Works by EDWARD THRING, M.A., Head Master of Uppingham.

THE ELEMENTS OF GRAMMAR TAUGHT IN ENGLISH, with Questions. Fourth Edition. 18mo. 75 Cents.

This little work is chiefly intended for teachers and learners. It took its rise from questionings in National Schools, and the whole of the first part is merely the writing out in order the answers to questions which have been used already with success. A chapter on Learning Language is especially addressed to teachers.

Thring—continued.

THE CHILD'S GRAMMAR. Being the Substance of "The Elements of Grammar taught in English," adapted for the Use of Junior Classes. A New Edition. 18mo. 40 Cents.

SCHOOL SONGS. A Collection of Songs for Schools. With the Music arranged for four Voices. Edited by the Rev. E. THRING and H. RICCIUS. Folio.

There is a tendency in schools to stereotype the forms of life. Any genial solvent is valuable. Games do much; but games do not penetrate to domestic life, and are much limited by age. Music supplies the want. The collection includes the "Agnus Dei," Tennyson's "Light Brigade," Macaulay's "Ivry," &c. among other pieces.

Trench (Archbishop).—HOUSEHOLD BOOK OF ENGLISH POETRY. Selected and Arranged, with Notes, by R. C. TRENCH, D.D., Archbishop of Dublin. Extra fcap. 8vo. \$2.25. Second Edition.

This volume is called a "Household Book," by this name implying that it is a book for all—that there is nothing in it to prevent it from being confidently placed in the hands of every member of the household. Specimens of all classes of poetry are given, including selections from living authors. The Editor has aimed to produce a book "which the emigrant, finding room for little not absolutely necessary, might yet find room for in his trunk, and the traveller in his knapsack, and that on some narrow shelves where there are few books this might be one." "The Archbishop has conferred in this delightful volume an important gift on the whole English-speaking population of the world."—PALL MALL GAZETTE.

ON THE STUDY OF WORDS. Lectures addressed (originally) to the Pupils at the Diocesan Training School, Winchester. Thirteenth Edition. Revised and Enlarged. Fcap. 8vo. \$1.25.

This, it is believed, was probably the first work which drew general attention in this country to the importance and interest of the critical and

historical study of English. It still retains its place as one of the most successful, if not the only, exponent of those aspects of words of which it treats. The subjects of the several Lectures are, (1) Introduction; (2) On the Poetry of Words; (3) On the Morality of Words; (4) On the History of Words; (5) On the Rise of New Words; (6) On the Distinction of Words; (7) The Schoolmaster's Use of Words.

ENGLISH, PAST AND PRESENT. Seventh Edition, revised and improved. Fcap. 8vo. \$1.25.

This is a series of Eight Lectures, in the first of which Archbishop Trench considers the English language as it now is, decomposes some specimens of it, and thus discovers of what element it is compact. In the second Lecture he considers what the language might have been if the Norman Conquest had never taken place. In the following six Lectures he institutes from various points of view a comparison between the present language and the past, points out gains which it has made, losses which it has endured, and generally calls attention to some of the more important changes through which it has passed, or is at present passing.

A SELECT GLOSSARY OF ENGLISH WORDS, used formerly in Senses Different from their Present. Third Edition. Fcap. 8vo. \$1.

This alphabetically arranged Glossary contains many of the most important of those English words which in the course of time have gradually changed their meanings. The author's object is to point out some of these changes, to suggest how many more there may be, to show how slight and subtle, while yet most real, these changes have often been, to trace here and there the progressive steps by which the old meaning has been put off and the new put on,—the exact road which a word has travelled. The author thus hopes to render some assistance to those who regard this as a serviceable discipline in the training of their own minds or the minds of others. Although the book is in the form of a Glossary, it will be found as interesting as a series of brief well-told biographies.

Yonge (Charlotte M.)—A PARALLEL HISTORY OF FRANCE AND ENGLAND : consisting of Outlines and Dates. By CHARLOTTE M. YONGE, Author of "The Heir of Redclyffe," "Comeos of English History," &c., &c. Oblong 4to. \$1'25.

This tabular history has been drawn up to supply a want felt by many teachers of some means of making their pupils realize what events in the two countries were contemporary. A skeleton narrative has been constructed of the chief transactions in either country, placing a column between for what affected both alike, by which means it is hoped that young people may be assisted in grasping the mutual relation of events. "We can imagine few more really advantageous courses of historical study for a young mind than going carefully and steadily through Miss Yonge's excellent little book."—EDUCATIONAL TIMES.

CAMEOS FROM ENGLISH HISTORY. From Rollo to Edward II. By the Author of "The Heir of Redclyffe." Extra fcap. 8vo. Second Edition, enlarged. \$1'50.

The endeavour has not been to chronicle facts, but to put together a series of pictures of persons and events, so as to arrest the attention, and give some individuality and distinctness to the recollection, by gathering together details at the most memorable moments. The "Comeos" are intended as a book for young people just beyond the elementary histories of England, and able to enter in some degree into the real spirit of events, and to be struck with characters and scenes presented in some relief. "Instead of dry details," says the NONCONFORMIST, "we have living pictures, faithful, vivid, and striking."

A SECOND SERIES OF CAMEOS FROM ENGLISH HISTORY.
THE WARS IN FRANCE. Extra fcap. 8vo. pp. xi. 415. \$1'50.

This new volume, closing with the Treaty of Arras, is the history of the struggles of Plantagenet and Valois. It refers, accordingly, to one of the most stirring epochs in the mediæval era, including the battle of Poitiers, the great Schism of the West, the Lollards, Agincourt and Joan of Arc. The authoress reminds her readers that she aims merely at "collecting from

Yonge (Charlotte M.)—continued.

the best authorities such details as may present scenes and personages to the eye in some fulness ;" her CAMEOS are a "collection of historical scenes and portraits such as the young might find it difficult to form for themselves without access to a very complete library." "Though mainly intended," says the JOHN BULL, "for young readers, they will, if we mistake not, be found very acceptable to those of more mature years, and the life and reality imparted to the dry bones of history cannot fail to be attractive to readers of every age."

EUROPEAN HISTORY. Narrated in a Series of Historical Selections from the Best Authorities. Edited and arranged by E. M. SEWELL and C. M. YONGE. First Series, 1003—1154. Crown 8vo. \$1.75. Second Series, 1088—1228. Crown 8vo. \$1.75.

*When young children have acquired the outlines of History from abridgments and catechisms, and it becomes desirable to give a more enlarged view of the subject, in order to render it really useful and interesting, a difficulty often arises as to the choice of books. Two courses are open, either to take a general and consequently dry history of facts, such as Russel's *Modern Europe*, or to choose some work treating of a particular period or subject, such as the works of Macaulay and Froude. The former course usually renders history uninteresting ; the latter is unsatisfactory because it is not sufficiently comprehensive. To remedy this difficulty, selections, continuous and chronological, have, in the present volume, been taken from the larger works of Freeman, Milman, Palgrave, and others, which may serve as distinct landmarks of historical reading. "We know of scarcely anything," says the GUARDIAN of this volume, "which is so likely to raise to a higher level the average standard of English education."*

THE ABRIDGED BOOK OF GOLDEN DEEDS. A Reading Book for Schools and General Readers. By the Author of "*The Heir of Redclyffe*." 18mo. cloth. 50 Cents.

A record of some of the good and great deeds of all time, abridged from the larger work of the same author in the Golden Treasury Series.

DIVINITY.

* * For other Works by these Authors, see THEOLOGICAL CATALOGUE.

Abbott (Rev. E. A.)—BIBLE LESSONS. By the Rev. E. A. ABBOTT, M.A., Head Master of the City of London School. Second Edition. Crown 8vo. \$1.50.

This book is written in the form of dialogues carried on between a teacher and pupil, and its main object is to make the scholar think for himself. The great bulk of the dialogues represents in the spirit, and often in the words, the religious instruction which the author has been in the habit of giving to the Fifth and Sixth Forms of the City of London School. The Author has endeavoured to make the dialogues thoroughly unsectarian. "Wise, suggestive, and really profound initiation into religious thought."—GUARDIAN. "I think nobody could read them without being both the better for them himself, and being also able to see how this difficult duty of imparting a sound religious education may be effected."—From BISHOP OF ST. DAVID'S SPEECH AT THE EDUCATION CONFERENCE AT ABERGWILLY.

Arnold.—A BIBLE-READING BOOK FOR SCHOOLS. The GREAT PROPHECY OF ISRAEL'S RESTORATION (Isaiah, Chapters 40—66). Arranged and Edited for Young Learners. By MATTHEW ARNOLD, D.C.L., formerly Professor of Poetry in the University of Oxford, and Fellow of Oriel. 18mo. cloth. 50 Cents.

"Schools for the people," the power of letters—which embraces nothing less than the whole history of the human spirit—has hardly been brought

to bear at all. Mr. Arnold, in this little volume, attempts to remedy this defect, by doing for the Bible what has been so abundantly done for Greek and Roman, as well as English authors, viz.—taking “some whole, of admirable literary beauty in style and treatment, of manageable length, within defined limits; and presenting this to the learner in an intelligible shape, adding such explanations and helps as may enable him to grasp it as a connected and complete work.” Mr. Arnold thinks it clear that nothing could more exactly suit the purpose than what the Old Testament gives us in the last twenty-seven chapters of the Book of Isaiah, beginning “Comfort ye” &c. He has endeavoured to present a perfectly correct text, maintaining at the same time the unparalleled balance and rhythm of the Authorised Version. In an Introductory note, Mr. Arnold briefly sums up the events of Jewish history to the starting-point of the chapters chosen; and in the copious notes appended, every assistance is given to the complete understanding of the text. There is nothing in the book to hinder the adherent of any school of interpretation or of religious belief from using it, and from putting it into the hands of children. The Preface contains much that is interesting and valuable on the relation of “letters” to education, of the principles that ought to guide the makers of a new version of the Bible, and other important matters. Altogether, it is believed, the volume will be found to form a text-book of the greatest value to schools of all classes. “Mr. Arnold has done the greatest possible service to the public. We never read any translation of Isaiah which interfered so little with the musical rhythm and associations of our English Bible translation, while doing so much to display the missing links in the connection of the parts.”—SPECTATOR.

Cheyne (T. K.)—THE BOOK OF ISAIAH CHRONOLOGICALLY ARRANGED. An Amended Version, with Historical and Critical Introductions and Explanatory Notes. By T. K. CHEYNE, M.A., Fellow of Balliol College, Oxford. Crown 8vo. \$2.25.

The object of this edition is simply to restore the probable meaning of Isaiah, so far as this can be expressed in modern English. The basis of the version is the revised translation of 1611, but no scruple has been felt in introducing alterations, wherever the true sense of the prophecies

appeared to require it. "A piece of scholarly work, very carefully and considerably done."—WESTMINSTER REVIEW.

Golden Treasury Psalter.—Students' Edition. Being an Edition of "The Psalms Chronologically Arranged, by Four Friends," with briefer Notes. 18mo. \$1.25.

In making this abridgment of "The Psalms Chronologically Arranged," the editors have endeavoured to meet the requirements of readers of a different class from those for whom the larger edition was intended. Some who found the large book useful for private reading, have asked for an edition of a smaller size and at a lower price, for family use, while at the same time some Teachers in Public Schools have suggested that it would be convenient for them to have a simpler book, which they could put into the hands of younger pupils. "It is a gem," says the NONCONFORMIST.

Hardwick.—A HISTORY OF THE CHRISTIAN CHURCH.

Middle Age. From Gregory the Great to the Excommunication of Luther. Edited by WILLIAM STUBBS, M.A., Regius Professor of Modern History in the University of Oxford. With Four Maps constructed for this work by A. KEITH JOHNSTON. Third Edition. Crown 8vo. \$3.

Although the ground-plan of this treatise coincides in many points with that of the colossal work of Schröckh, yet in arranging the materials a very different course has frequently been pursued. With regard to his opinions the late author avowed distinctly that he construed history with the specific prepossessions of an Englishman and a member of the English Church. The reader is constantly referred to the authorities, both original and critical, on which the statements are founded. For this edition Professor Stubbs has carefully revised both text and notes, making such corrections of facts, dates, and the like as the results of recent research warrant. The doctrinal, historical, and generally speculative views of the late author have been preserved intact. "As a manual for the student of ecclesiastical history in the Middle Ages, we know no English work which can be compared to Mr. Hardwick's book."—GUARDIAN.

Hardwick—continued.

A HISTORY OF THE CHRISTIAN CHURCH DURING THE REFORMATION. By ARCHDEACON HARDWICK. Revised by FRANCIS PROCTER, M.A. Second Edition. Crown 8vo.

[In the Press.

This volume is intended as a sequel and companion to the "History of the Christian Church during the Middle Age." The author's earnest wish has been to give the reader a trustworthy version of those stirring incidents which mark the Reformation period, without relinquishing his former claim to characterise peculiar systems, persons, and events according to the shades and colours they assume, when contemplated from an English point of view, and by a member of the Church of England.

Maclear.—Works by the Rev. G. F. MACLEAR, D.D., Head Master of King's College School, and Preacher at the Temple Church.

A CLASS-BOOK OF OLD TESTAMENT HISTORY. Sixth Edition, with Four Maps. 18mo. cloth. \$1.50.

This volume forms a Class-book of Old Testament History from the earliest times to those of Ezra and Nehemiah. In its preparation the most recent authorities have been consulted, and wherever it has appeared useful, Notes have been subjoined illustrative of the Text, and, for the sake of more advanced students, references added to larger works. The Index has been so arranged as to form a concise dictionary of the persons and places mentioned in the course of the narrative; while the Maps, which have been prepared with considerable care at Stanford's Geographical Establishment, will, it is hoped, materially add to the value and usefulness of the Book. "A careful and elaborate though brief compendium of all that modern research has done for the illustration of the Old Testament. We know of no work which contains so much important information in so small a compass."—BRITISH QUARTERLY REVIEW.

A CLASS-BOOK OF NEW TESTAMENT HISTORY, including the Connexion of the Old and New Testament. With Four Maps. Third Edition. 18mo. cloth. \$1.50.

A sequel to the author's Class-book of Old Testament History, continuing the narrative from the point at which it there ends, and carrying it on to

Maclear—continued.

the close of St. Paul's second imprisonment at Rome. In its preparation, as in that of the former volume, the most recent and trustworthy authorities have been consulted, notes subjoined, and references to larger works added. It is thus hoped that it may prove at once an useful class-book and a convenient companion to the study of the Greek Testament. "A singularly clear and orderly arrangement of the Sacred Story. His work is solidly and completely done."—ATHENÆUM.

ABRIDGED CLASS-BOOK OF OLD TESTAMENT HISTORY, for National and Elementary Schools. With Map. 18mo. cloth. 50 Cents.

ABRIDGED CLASS-BOOK OF NEW TESTAMENT HISTORY, for National and Elementary Schools. With Map. 18mo. cloth. 50 Cents.

These works have been carefully abridged from the author's larger manuals.

CLASS-BOOK OF THE CATECHISM OF THE CHURCH OF ENGLAND. Second Edition. 18mo. cloth. 75 Cents.

This may be regarded as a sequel to the Class-books of Old and New Testament History. Like them, it is furnished with notes and references to larger works, and it is hoped that it may be found, especially in the higher forms of our Public Schools, to supply a suitable manual of instruction in the chief doctrines of the English Church, and a useful help in the preparation of candidates for Confirmation. "It is indeed the work of a scholar and divine, and as such, though extremely simple, it is also extremely instructive. There are few clergymen who would not find it useful in preparing candidates for Confirmation; and there are not a few who would find it useful to themselves as well."—LITERARY CHURCHMAN.

A FIRST CLASS-BOOK OF THE CATECHISM OF THE CHURCH OF ENGLAND, with Scripture Proofs, for Junior Classes and Schools. 18mo. 20 Cents.

THE ORDER OF CONFIRMATION. A Sequel to the Class Book of the Catechism. For the use of Candidates for Confirmation. With Prayers and Collects. 18mo. 10 Cents.

Maurice.—THE LORD'S PRAYER, THE CREED, AND THE COMMANDMENTS. A Manual for Parents and Schoolmasters. To which is added the Order of the Scriptures. By the Rev. F. DENISON MAURICE, M.A. Professor of Moral Philosophy in the University of Cambridge. 18mo. cloth limp. 50 Cents.

Procter.—A HISTORY OF THE BOOK OF COMMON PRAYER, with a Rationale of its Offices. By FRANCIS PROCTER, M.A. Tenth Edition, revised and enlarged. Crown 8vo. \$3.50.

In the course of the last twenty years the whole question of Liturgical knowledge has been reopened with great learning and accurate research ; and it is mainly with the view of epitomizing extensive publications, and correcting the errors and misconceptions which had obtained currency, that the present volume has been put together. "We admire the author's diligence, and bear willing testimony to the extent and accuracy of his reading. The origin of every part of the Prayer Book has been diligently investigated, and there are few questions of facts connected with it which are not either sufficiently explained, or so referred to that persons interested may work out the truth for themselves."—ATHENÆUM.

Procter and Maclear.—AN ELEMENTARY INTRODUCTION TO THE BOOK OF COMMON PRAYER. Re-arranged and supplemented by an Explanation of the Morning and Evening Prayer and the Litany. By the Rev. F. PROCTER and the Rev. G. F. MACLEAR. Fourth Edition. 18mo. 75 Cents.

As in the other Class-books of the series, notes have also been subjoined, and references given to larger works, and it is hoped that the volume will be found adapted for use in the higher forms of our Public Schools, and a suitable manual for those preparing for the Oxford and Cambridge local examinations. This new Edition has been considerably altered, and several important additions have been made. Besides a re-arrangement of the work generally, the Historical Portion has been supplemented by an Explanation of the Morning and Evening Prayer and of the Litany.

Psalms of David Chronologically Arranged. By Four Friends. An Amended Version, with Historical Introduction and Explanatory Notes. Second and Cheaper Edition, with Additions and Corrections. Crown 8vo. \$2'25.

To restore the Psalter as far as possible to the order in which the Psalms were written,—to give the division of each Psalm into strophes, of each strophe into the lines which composed it,—to amend the errors of translation, is the object of the present Edition. Professor Ewald's works, especially that on the Psalms, have been extensively consulted. This book has been used with satisfaction by masters for private work in higher classes in schools. The SPECTATOR calls this "one of the most instructive and valuable books that has been published for many years."

Ramsay.—THE CATECHISER'S MANUAL; or, the Church Catechism Illustrated and Explained, for the use of Clergymen, Schoolmasters, and Teachers. By the Rev. ARTHUR RAMSAY, M.A. Second Edition. 18mo. 50 Cents.

A clear explanation of the Catechism, by way of Question and Answer. "This is by far the best Manual on the Catechism we have met with."
—ENGLISH JOURNAL OF EDUCATION.

Simpson.—AN EPITOME OF THE HISTORY OF THE CHRISTIAN CHURCH. By WILLIAM SIMPSON, M.A. Fifth Edition. Fcap. 8vo. \$1.

A compendious summary of Church History.

Swainson.—A HANDBOOK to BUTLER'S ANALOGY. By C. A. SWAINSON, D.D., Canon of Chichester. Crown 8vo. 75 Cents.

This manual is designed to serve as a handbook or road-book to the Student in reading the Analogy, to give the Student a sketch or outline map of the country on which he is entering, and to point out to him matters of interest as he passes along.

Trench.—SYNONYMS OF THE NEW TESTAMENT. By R. CHEVENIX TRENCH, D.D., Archbishop of Dublin. New Edition, enlarged. 8vo. cloth. \$3'50.

The study of synonyms in any language is valuable as a discipline for training the mind to close and accurate habits of thought: more especially is this the case in Greek—"a language spoken by a people of the finest and subtlest intellect; who saw distinctions where others saw none; who divided out to different words what others often were content to huddle confusedly under a common term. This work is recognised as a valuable companion to every student of the New Testament in the original. This, the Seventh Edition, has been carefully revised, and a considerable number of new synonyms added. Appended is an Index to the Synonyms, and an Index to many other words alluded to or explained throughout the work. "He is," the ATHENÆUM says, "a guide in this department of knowledge to whom his readers may intrust themselves with confidence. His sober judgment and sound sense are barriers against the misleading influence of arbitrary hypotheses."

Westcott.—Works by BROOKE FOSS WESTCOTT, B.D., Canon of Peterborough.

A GENERAL SURVEY OF THE HISTORY OF THE CANON OF THE NEW TESTAMENT DURING THE FIRST FOUR CENTURIES. Third Edition, revised. Crown 8vo. \$3'50.

The author has endeavoured to connect the history of the New Testament Canon with the growth and consolidation of the Church, and to point out the relation existing between the amount of evidence for the authenticity of its component parts, and the whole mass of Christian literature. Such a method of inquiry will convey both the truest notion of the connection of the written Word with the living Body of Christ, and the surest conviction of its divine authority. Of this work the SATURDAY REVIEW writes: "Theological students, and not they only, but the general public, owe a deep debt of gratitude to Mr. Westcott for bringing this subject fairly before them in this candid and comprehensive essay. . . . As a theological work it is

at once perfectly fair and impartial, and imbued with a thoroughly religious spirit; and as a manual it exhibits, in a lucid form and in a narrow compass, the results of extensive research and accurate thought. We cordially recommend it."

INTRODUCTION TO THE STUDY OF THE FOUR GOSPELS.

Fourth Edition. Crown 8vo. \$3.50.

The Author's chief object in this work is to show that there is a true mean between the idea of a formal harmonization of the Gospels and the abandonment of their absolute truth. The treatise consists of eight chapters:—I. The Preparation for the Gospel. II. The Jewish Doctrine of the Messiah. III. The Origin of the Gospels. IV. The Characteristics of the Gospels. V. The Gospel of St. John. VI. & VII. The Differences in detail and of arrangement in the Synoptic Evangelists. VIII. The Difficulties of the Gospels. "To a learning and accuracy which commands respect and confidence, he unites what are not always to be found in union with these qualities, the no less valuable faculties of lucid arrangement and graceful and facile expression."—LONDON QUARTERLY REVIEW.

A GENERAL VIEW OF THE HISTORY OF THE ENGLISH BIBLE. Crown 8vo. \$3.50.

"The first trustworthy account we have had of that unique and marvellous monument of the piety of our ancestors."—DAILY NEWS.

"A brief, scholarly, and, to a great extent, an original contribution to theological literature. He is the first to offer any considerable contributions to what he calls their internal history, which deals with their relation to other texts, with their filiation one on another, and with the principles by which they have been successively modified."—PALL MALL GAZETTE.

THE BIBLE IN THE CHURCH. A Popular Account of the Collection and Reception of the Holy Scriptures in the Christian Churches. Third Edition. 18mo. cloth. \$1.25.

The present book is an attempt to answer a request, which has been made from time to time, to place in a simple form, for the use of general readers,

the substance of the author's "History of the Canon of the New Testament." An elaborate and comprehensive Introduction is followed by chapters on the Bible of the Apostolic Age; on the Growth of the New Testament; the Apostolic Fathers; the Age of the Apologists; the First Christian Bible; the Bible Proscribed and Restored; the Age of Jerome and Augustine; the Bible of the Middle Ages in the West and in the East, and in the Sixteenth Century. Two appendices on the History of the Old Testament Canon before the Christian Era, and on the Contents of the most ancient MSS. of the Christian Bible, complete the volume. "We would recommend every one who loves and studies the Bible to read and ponder this exquisite little book. Mr. Westcott's account of the 'Canon' is true history in its highest sense."—LITERARY CHURCHMAN.

THE GOSPEL OF THE RESURRECTION. Thoughts on its Relation to Reason and History. New Edition. Fcap. 8vo. \$1.50.

This Essay is an endeavour to consider some of the elementary truths of Christianity as a miraculous Revelation, from the side of History and Reason. If the arguments which are here adduced are valid, they will go far to prove that the Resurrection, with all that it includes, is the key to the history of man, and the complement of reason.

Wilson.—**THE BIBLE STUDENTS' GUIDE** to the more Correct Understanding of the English translation of the Old Testament, by reference to the Original Hebrew. By WILLIAM WILSON, D.D., Canon of Winchester, late Fellow of Queen's College, Oxford. Second Edition, carefully Revised. 4to. cloth. \$10.

This work is the result of almost incredible labour bestowed on it during many years. Its object is to enable the readers of the Old Testament Scriptures to penetrate into the real meaning of the sacred writers. All the English words used in the Authorized Version are alphabetically arranged, and beneath them are given the Hebrew equivalents, with a careful explanation of the peculiar signification and construction of each term. The knowledge of the Hebrew language is not absolutely necessary to the profitable use of the work. Devout and accurate students of the Bible, entirely unacquainted with Hebrew, may derive great advantage from frequent

reference to it. It is especially adapted for the use of the clergy. "For ~~all~~ earnest students of the Old-Testament Scriptures it is a most valuable Manual. Its arrangement is so simple that those who possess only their mother-tongue, if they will take a little pains, may employ it with great profit."—NONCONFORMIST.

Yonge (Charlotte M.)—SCRIPTURE READINGS FOR SCHOOLS AND FAMILIES. By CHARLOTTE M. YONGE, Author of "The Heir of Redclyffe." Globe 8vo. 75 Cents. With Comments, \$1.50.

A SECOND SERIES. From JOSHUA to SOLOMON. Extra fcap. 75 Cents. With Comments, \$1.50.

Actual need has led the author to endeavour to prepare a reading book convenient for study with children, containing the very words of the Bible, with only a few expedient omissions, and arranged in Lessons of such length as by experience she has found to suit with children's ordinary power of accurate attentive interest. The verse form has been retained, because of its convenience for children reading in class, and as more resembling their Bibles; but the poetical portions have been given in their lines. When Psalms or portions from the Prophets illustrate or fall in with the narrative they are given in their chronological sequence. The Scripture portion, with a very few notes explanatory of mere words, is bound up apart, to be used by children, while the same is also supplied with a brief comment, the purpose of which is either to assist the teacher in explaining the lesson, or to be used by more advanced young people to whom it may not be possible to give access to the authorities whence it has been taken. Professor Huxley, at a meeting of the London School Board, particularly mentioned the selection made by Miss Yonge as an example of how selections might be made from the Bible for School Reading. See TIMES, March 30, 1871.

38, BLEECKER STREET,
NEW YORK.

CLARENDON PRESS SERIES.

The attention of College Lecturers, Schoolmasters, and all persons interested in Education is especially directed to the following series of works, most of which have been lately issued from the Clarendon Press, and are written with immediate reference to the present state of science and learning, and to urgent educational needs.

"Such manuals, so admirable in matter, arrangement, and type, were never before given to the world at the same moderate price."—SPECTATOR.

I.—PROFESSOR BREWER'S SERIES OF ENGLISH CLASSICS.

Chaucer.—THE PROLOGUE TO THE CANTERBURY TALES ; The Knightes Tale ; The Nonne Prestes Tale. Edited by R. MORRIS. Extra fcap. 8vo., cloth, \$1.

"With such assistance the ordinary reader will have no difficulty in appreciating Chaucer, and will be grateful to Mr. Morris for having guided him in such a pleasant path."—SPECTATOR.

Spenser's FAERY QUEENE. Books I. and II. Designed chiefly for the use of Schools. With Introduction, Notes, and Glossary. By G. W. KITCHIN, M.A. Extra fcap. 8vo., cloth, \$1 each.

"Admirably fitted for use in Schools and Colleges where the English language forms, as it ought to do everywhere, a part of the ordinary curriculum."—PALL MALL GAZETTE.

Hooker.—ECCLESIASTICAL POLITY, Book I. Edited by the Rev. R. W. CHURCH, M.A.; formerly Fellow of Oriel College. Extra fcap. 8vo., cloth, \$1.

"This volume merits our commendation for the care and completeness with which it is edited."—EDUCATIONAL TIMES.

Shakespeare.—Select Plays. Edited by W. G. CLARK, M.A., Fellow of Trinity College, Cambridge; and W. ALDIS WRIGHT, M.A., Trinity College, Cambridge.

I. THE MERCHANT OF VENICE. Extra fcap. 8vo.
40 Cents.

II. RICHARD THE SECOND. Extra fcap. 8vo. 60 Cents.

III. MACBETH. Extra fcap. 8vo. 60 Cents.

IV. HAMLET. Extra fcap. 8vo. 75 Cents.

"The notes are copious and exhaustive, and leave no difficulty of the text unexplained."—EDUCATIONAL TIMES.

Bacon.—ADVANCEMENT OF LEARNING. Edited by W. ALDIS WRIGHT, M.A. Extra fcap. 8vo. cloth, \$1.75.

"We do not know what could be done more for the illustration of a great work than Mr Wright has done."—PALL MALL GAZETTE.

Milton.—POEMS. Edited by R. C. BROWNE, M.A., and Associate of King's College, London. 2 vols. Extra fcap. 8vo., cloth, \$2.25. Separately, Vol. I., \$1.25; Vol. II., \$1.25.

Milton—continued.

"A first-rate School or College edition, and we should hope that the study of our mother tongue is so far advancing among us that there may be many schools and colleges where it will be gladly welcomed and largely used."—LITERARY CHURCHMAN.

Dryden.—SELECT POEMS. Stanzas on the Death of Oliver Cromwell; Astræa Redux; Annus Mirabilis; Absalom and Ahithophel; Religio Laici; the Hind and the Panther. Edited by W. D. CHRISTIE, M.A., Trinity College, Cambridge. Extra fcap. 8vo., cloth, \$1.50.

"The poems selected are all of importance, and the excellent notes, and the biography of the poet, leave very little to be desired. For convenience, for excellence of editing, and for clearness of type, Mr. Christie's book is much to be commended."—ACADEMY.

Pope.—ESSAY ON MAN. With Introduction and Notes. By MARK PATTISON, B.D., Rector of Lincoln College, Oxford. Extra fcap. 8vo., stiff covers, 50 Cents.

"Every page shows the refinement and subtlety of thought of the distinguished editor, and his intimate acquaintance, not merely with the literature, but also with the sources of the literature, of our so-called Augustan age."—CONTEMPORARY REVIEW.

Pope.—SATIRES AND EPISTLES. By the same Editor. Extra fcap. 8vo., 75 Cents.

"This is really a signal example of elegant and faithful elucidation and comment. The work is done here with such fulness of knowledge and liveliness of illustration that the notes are fully as interesting in their way as the poems they explain."—LITERARY CHURCHMAN.

"No one that has any real interest in Pope should omit to read the introductory remarks on the merits and demerits of his satirical poetry."—GUARDIAN.

SPECIMENS OF EARLY ENGLISH. A new and revised Edition. With Introduction, Notes, and Glossarial Index. By R. MORRIS, LL.D., and W. W. SKEAT, M.A. Part II. From Robert of Gloucester to Gower (A.D. 1298—A.D. 1393). Extra fcap. 8vo., cloth, \$3.

SPECIMENS OF ENGLISH LITERATURE, from the "Ploughmans Crede" to the "Shepheardes Calender" (A.D. 1394—A.D. 1579). With Introduction, Notes, and Glossarial Index. By W. W. SKEAT, M.A. Extra fcap. 8vo., cloth, \$3.

"Two admirable volumes. The selections are exactly what they should be, and each volume has an independent glossary, and ample help in the notes for all attentive students."—STANDARD.

II.—ENGLISH LANGUAGE AND LITERATURE.

THE PHILOLOGY OF THE ENGLISH TONGUE. By J. EARLE, M.A., formerly Fellow of Oriel College, and Professor of Anglo-Saxon, Oxford. Extra fcap. 8vo., cloth, \$2.

"The work of a competent scholar, illustrating with much copiousness the subject with which he has been long familiar . . . Its great essential merit is sure to be ultimately recognized."—GUARDIAN.

"Every page of the work attests Mr. Earle's thorough knowledge of English in all its stages, and of the living Teutonic languages."—ACADEMY.

"Mr. Earle's book commends itself as the mature fruit of wide scholarship and practised philological ingenuity."—EXAMINER.

"It is a book which ought to be in every good school and in every house; especially where there are young people whom it is desirable to win to the love of an intelligent comprehension of their own tongue."—LITERARY CHURCHMAN.

"We believe it will become a standard work, superseding (as it ought to do) all others."—ENGLISH CHURCHMAN.

THE VISION OF WILLIAM CONCERNING PIERS THE PLOWMAN. By WILLIAM LANGLAND. Edited, with Introduction and Notes, by W. W. SKEAT, M.A., formerly Fellow of Christ's College, Cambridge. Extra fcap. 8vo., cloth, \$1.

"The editor contributes an Introduction in which all the information that is necessary is given concerning the poem and its author, a body of Notes which are very satisfactory, and a Glossary which is indispensable for the use of the volume for educational purposes. It is an admirable form in which to make acquaintance with Langland's work."—LONDON QUARTERLY REVIEW.

TYPICAL SELECTIONS FROM THE BEST ENGLISH AUTHORS from the Sixteenth to the Nineteenth Century (to serve as a higher Reading Book), with Introductory Notices and Notes, being a Contribution towards a History of English Literature. Extra fcap. 8vo., cloth, \$1.50.

"A beautifully printed and judiciously selected reading book for the use of schools, containing extracts from fifty-nine of our best prose authors; each extract being preceded by an introductory notice of the author, supplying really sound and useful criticism on his literary merits and defects."—EDUCATIONAL TIMES.

A FIRST READING BOOK. By MARIE EICHENS, of Berlin; edited by ANNE J. CLOUGH. Extra fcap. 8vo., stiff covers, 15 Cents.

"It makes good its claim to special consideration, as proceeding on a more natural system than ordinary pioneers, and therefore as being more attractive and likely to be useful."—STANDARD.

OXFORD READING BOOK. For Junior Classes. Extra fcap. 8vo., stiff covers, 60 Cents.

"A very healthy and amusing collection of short extracts in prose and verse, such as boys and girls who are able to read with tolerable fluency will delight in."—GUARDIAN.

ON THE PRINCIPLES OF GRAMMAR. By E. THRING, M.A.,
Head Master of Uppingham School. Extra fcap. 8vo., cloth,
\$1.50.

GRAMMATICAL ANALYSIS. By the same Author. Extra
fcap. 8vo., cloth, \$1.

III.—FRENCH CLASSICS.

Edited, with Introductions and Notes, by GUSTAVE MASSON, B.A.,
Univ. Gallic., Assistant Master in Harrow School.

CORNEILLE'S CINNA, and MOLIÈRE'S LES FEMMES
SAVANTES. Extra fcap. 8vo., cloth, \$1.

RACINE'S ANDROMAQUE, and CORNEILLE'S LE MEN-
TEUR. With Louis Racine's Life of his Father. Extra fcap.
8vo., cloth, \$1.

MOLIÈRE'S LES FOURBERIES DE SCAPIN, and RACINE'S
ATHALIE. With Voltaire's Life of Molière. Extra fcap. 8vo.,
cloth, \$1.

SELECTIONS FROM THE CORRESPONDENCE OF
MADAME DE SÉVIGNÉ and HER CHIEF CONTEM-
PORARIES. Intended more especially for Girls' Schools. Extra
fcap. 8vo., cloth, \$1.

VOYAGE AUTOUR DE MA CHAMBRE, by XAVIER DE MAIS-
TRE; OURIKA, by MADAME DE DURAS; LA DOT DE
SUZETTE, by FIEVÉE; LES JUMENTS DE L'HOTEL
CORNEILLE, by EDMOND ABOUT; MÉSAVENTURES D'UN
ÉCOLIER, by RODOLPHE TÖPFFER. Extra fcap. 8vo., cloth, \$1.

*"Students of French ought to make acquaintance with modern
French literature, and M. Masson is well qualified to be their guide."*—
NONCONFORMIST.

BRACHET'S HISTORICAL GRAMMAR OF THE FRENCH LANGUAGE. Translated into English by G. W. KITCHIN, M.A. Extra fcap. 8vo., cloth, \$1.25.

"This admirable study of the French tongue, in its relation to ancient and modern languages, should find its way into the hands of all those who are interested in Comparative Philology."—EDUCATIONAL TIMES.

IV.—GERMAN CLASSICS.

By Dr. BUCHHEIM, Professor of the German Language and Literature in King's College, London; and Examiner in German to the University of London.

GOETHE'S EGMONT. With a Life of Goethe; an Historical and Critical Introduction, Arguments to the Acts, and Commentary. Ext. fcap. 8vo., cloth, \$1.25.

SCHILLER'S WILHELM TELL. With a Life of Schiller, an Historical and Critical Introduction, Arguments, and a complete Commentary. Ext. fcap. 8vo., cloth, \$1.25.

"The 'Tell' of Schiller has been edited in the same intelligent and scholarly manner as the 'Egmont.' Both books are worthy of the Clarendon Press Series, and will be of great value to the student of the German language and literature."—MORNING POST.

V.—LATIN CLASSICS.

CÆSAR. The Commentaries (for Schools). Part I. The Gallic War, with Notes, Maps, &c., by CHARLES E. MOBERLY, M.A., Assistant Master in Rugby School; formerly Scholar of Balliol College, Oxford. Ext. fcap. 8vo., cloth, \$1.50.

"An admirable edition, and will be found a most useful school-book."
—JOHN BULL.

Part II. The Civil War. Book I. By the same Editor. 75 Cents.
[Just published.]

CICERO'S PHILIPPIC ORATIONS. With English Notes, by the Rev. J. R. KING, M.A., formerly Fellow and Tutor of Merton College, Oxford. Demy 8vo., \$3.50.

CICERO. SELECT LETTERS. With Introductions, Notes, and Appendices, by ALBERT WATSON, M.A., Fellow and Tutor of Brasenose College, Oxford. Demy 8vo., cloth, \$6.50.

"Mr. Watson's critical labours are soundly and sensibly executed, and we make no doubt that his 'Select Letters' will be found a very serviceable volume to scholars, younger and older."—SATURDAY REVIEW.

"The Notes are careful, clear, and adequate; and would alone render the volume a valuable addition to the Series in which it appears."—THE ACADEMY.

CICERO. SELECTED LETTERS (for Schools). With Notes. By the late C. E. PRICHARD, M.A., formerly Fellow of Balliol College, Oxford, and E. R. BERNARD, M.A., Fellow of Magdalen College, Oxford. Extra fcap. 8vo., cloth, \$1.

"In the selection of the letters due care has been taken to secure variety of interest, and the specimens given are well fitted to inspire intelligent pupils with a real liking for classical literature. Ample notes supply all that seems necessary in the way of philological exposition and historical illustration."—SCOTSMAN.

CICERO PRO CLUENTIO. With Introduction and English Notes. By the late Professor W. RAMSAY, M.A. Edited by G. G. RAMSAY, M.A., Professor of Humanity, Glasgow College. Extra fcap. 8vo., cloth, \$1.25.

"The exceedingly difficult and complicated questions of Roman law involved in the case are treated with clearness and precision, and the tangled web of the story told in the Oration is made plain. . . . The student could not have a better guide than he will find here."—SPECTATOR.

CICERO. SELECTION OF INTERESTING AND DESCRIPTIVE PASSAGES. With Notes. By HENRY WALFORD, M.A., Wadham College, Oxford, Assistant Master at Haileybury College. In three Parts. Extra fcap. 8vo., cloth, \$1.50.

Each Part separately, in limp cloth, 60 Cents.

Part I. Anecdotes from Grecian and Roman History.

Part II. Omens and Dreams: Beauties of Nature.

Part III. Rome's Rule of her Provinces.

"A serviceable school book, containing all needful explanatory and illustrative information."—ATHENÆUM.

CORNELIUS NEPOS. With English Notes. By OSCAR BROWNING, M.A. Extra fcap. 8vo., \$1.

LIVY, BOOKS I—X. By J. R. SEELEY, M.A., Fellow of Christ's College, and Regius Professor of Modern History, Cambridge. Book I. 8vo., cloth, \$2.50.

"The historical part is characterised by a judicial impartiality which carries conviction; the scholarship bears the marks of being written by one who has had the training of being Professor of Latin before he was Professor of History."—THE GLOBE.

"We are convinced that if Mr. Seeley's continuation of his editorial task upon Livy is as thorough as its commencement, he will not only succeed in making the ground of early Roman history safer and surer footing, but also will enhance appreciably the already sensible pleasure of studying one of the most brilliant and pictorial of ancient historians."—SATURDAY REVIEW.

OVID. SELECTIONS FOR THE USE OF SCHOOLS. With Introductions and Notes, and an Appendix on the Roman Calendar. By the late Professor W. RAMSAY, M.A. Edited by G. G. RAMSAY, M.A., Professor of Humanity, Glasgow College. Second Edition. Extra fcap. 8vo., \$1.75.

SELECTIONS FROM THE LESS KNOWN LATIN POETS.

By NORTH PINDER, M.A., formerly Fellow of Trinity College, Oxford. Demy 8vo., cloth, \$6.50.

PASSAGES FOR TRANSLATION INTO LATIN. For the use

of Passmen and others. Selected by J. Y. SARGENT, M.A., Tutor, and formerly Fellow, of Magdalen College, Oxford. Second Edition. Extra fcap. 8vo., cloth, \$1.

PERSIUS. THE SATIRES. With a Translation and Commentary.

By JOHN CONINGTON, M.A., late Corpus Professor of Latin in the University of Oxford. Edited by HENRY NETTLESHIP, M.A., formerly Fellow of Lincoln College, Oxford. 8vo., cloth, \$3.

PLINY. SELECTED LETTERS (for Schools). By the late C. E.

PRICHARD, M.A., formerly Fellow of Balliol College, Oxford, and E. R. BERNARD, M.A., Fellow of Magdalen College, Oxford. Extra fcap. 8vo., cloth, \$1.

VI.—GREEK CLASSICS.

A GREEK PRIMER IN ENGLISH, for the use of beginners. By the Right Rev. CHARLES WORDSWORTH, D.C.L. Extra fcap. 8vo., cloth, 60 Cents.

"We need scarcely say more of it than that it is an adaptation by Dr. Wordsworth of his own well-known 'Greek Grammar' to the special wants of those who are beginning to learn Greek. It would be difficult to suggest any improvement in it."—STANDARD.

GREEK VERBS, IRREGULAR AND DEFECTIVE ; their forms, meaning, and quantity ; embracing all the Tenses used by Greek writers, with references to the passages in which they are found. By W. VEITCH, LL.D. New Edition. Crown 8vo., cloth, \$4.

"A work of priceless value to every scholar."—EDUCATIONAL TIMES.

THE GOLDEN TREASURY OF ANCIENT GREEK POETRY ;

being a collection of the finest passages in the Greek Classic Poets, with Introductory Notices and Notes. By R. S. WRIGHT, M.A., Fellow of Oriel College, Oxford. Extra fcap. 8vo., cloth, \$4.50.

THE GOLDEN TREASURY OF GREEK PROSE, being a collection

of the finest passages in the principal Greek Prose Writers, with Introductory Notices and Notes. By R. S. WRIGHT, M.A., Fellow of Oriel College, Oxford ; and J. E. L. SHADWELL, M.A., Student of Christ Church. Extra fcap. 8vo., cloth, \$2.25.

THE ELEMENTS OF GREEK ACCENTUATION (for Schools):

abridged from his larger work by H. W. CHANDLER, M.A., Waynflete Professor of Moral and Metaphysical Philosophy, Oxford. Extra fcap. 8vo., cloth, \$1.

SOPHOCLES. THE PLAYS AND FRAGMENTS. With English Notes and Introductions. By LEWIS CAMPBELL, M.A., Professor of Greek, St. Andrew's, formerly Fellow of Queen's College, Oxford. In Two Volumes.

Vol. I. **ŒDIPUS TYRANNUS. ŒDIPUS COLONEUS. ANTIGONE.** 8vo., cloth, \$6.

"This edition is one which no one can read without finding his knowledge of Sophocles substantially increased."—THE ACADEMY.

"The notes appended to the text are of the most complete and comprehensive character, clearing up every difficulty and obscurity likely to puzzle the student. . . . The student who seeks Professor Campbell's assistance to help him to a knowledge of Greek tragedy will find at once a most agreeable and a most competent guide."—SCOTSMAN.

SOPHOCLES. ŒDIPUS REX, DINDORF'S TEXT. With

English Notes by the Ven. Archdeacon BASIL JONES, M.A., formerly Fellow of University College. Extra fcap. 8vo., cloth 60 Cents.

THEOCRITUS (for Schools). With Notes. By H. SNOW, M.A., Assistant Master at Eton College, formerly Fellow of St. John's College, Cambridge. Extra fcap. 8vo., cloth, \$1.50.

HOMER, ODYSSEY I—XII (for Schools). By the Rev. W. W. MERRY, M.A., Fellow and Lecturer of Lincoln College, Oxford. Extra fcap. 8vo., cloth, \$1.50.

"The book before us is singularly good and complete for a school-book. It reminds us more of a critical edition, reduced in scale. The sketch of the Homeric forms and elucidation of the syntax is especially good and useful."—LITERARY CHURCHMAN.

"A good school-book, with features likely to be particularly attractive to boys."—GUARDIAN.

XENOPHON. SELECTIONS (for Schools). With Notes and Maps, by J. S. PHILLPOTTS, M.A., Assistant Master in Rugby School, formerly Fellow of New College, Oxford. Extra fcap. 8vo., cloth, \$1.25.

"Mr. Phillpotts has attempted to 'forge Xenophon's Hellenics into another weapon for the teachers armoury,' and we congratulate him upon the brilliancy and perfection of his weapon. We would most strongly recommend his excellent notes to the teachers in our Northern schools."—SCOTSMAN.

"It is not often our good fortune to meet with a work at once so scholarly and so practical."—ATHENÆUM.

VII.—HISTORY.

SELECT CHARTERS AND OTHER HISTORICAL DOCUMENTS, illustrative of the Constitutional History of the English Nation from the Earliest Times to the reign of Edward I. By W. STUBBS, M.A., Regius Professor of Modern History in the University of Oxford. Crown 8vo., cloth, \$3.50.

"Here is a book of Select Charters which Mr. Stubbs simply claims to have 'arranged and edited.' No one would guess from this that he has thrown in, in the casual way in which he does throw things in, a sketch

of the early constitutional history of England, such as has never been written before. . . . In the Introductory Sketch we get the constitutional history of our race for about thirteen hundred years, written with such combined learning, power, and clearness as to put it beyond the reach of living competition."—SATURDAY REVIEW.

A MANUAL OF ANCIENT HISTORY. By GEORGE RAWLINSON, M.A., Camden Professor of Ancient History, formerly Fellow of Exeter College, Oxford. Demy 8vo., cloth, \$3.

VIII.—PHYSICAL SCIENCE AND MATHEMATICS.

A TREATISE ON NATURAL PHILOSOPHY. Vol. I. By Sir W. THOMSON, LL.D., D.C.L., F.R.S., Professor of Natural Philosophy in the University of Glasgow, and P. G. TAIT, M.A., Professor of Natural Philosophy in the University of Edinburgh; formerly Fellows of St. Peter's College, Cambridge. New Edition. [In the Press.

ELEMENTS OF NATURAL PHILOSOPHY. By the same Authors. Part I.

[Nearly ready.

AN ELEMENTARY TREATISE ON QUATERNIONS. By P. G. TAIT, M.A., Professor of Natural Philosophy in the University of Edinburgh; formerly Fellow of St. Peter's College, Cambridge. Demy 8vo., \$6.

AN ELEMENTARY TREATISE ON HEAT, with numerous Woodcuts and Diagrams. By BALFOUR STEWART, LL.D., F.R.S., Director of the Observatory at Kew. Second Edition. Extra fcap. 8vo., cloth, \$2.50.

A TREATISE ON ACOUSTICS. By W. F. DONKIN, M.A. F.R.S., Savilian Professor of Astronomy, Oxford. Crown 8vo., cloth, \$3.50.

DESCRIPTIVE ASTRONOMY. A Handbook for the General Reader, and also for practical Observatory work. With 224 illustrations and numerous tables. By G. F. CHAMBERS, F.R.A.S. Demy 8vo., cloth, \$8.

CHEMISTRY FOR STUDENTS. By A. W. WILLIAMSON, Phil. Doc., F.R.S., Professor of Chemistry, University College, London. Second Edition, with Solutions. Extra fcap. 8vo., cloth, \$2.50.

EXERCISES IN PRACTICAL CHEMISTRY. By A. G. VERNON HARCOURT, M.A., F.R.S., Senior Student of Christ Church, and Lee's Reader in Chemistry; and H. G. MADAN, M.A., Fellow of Queen's College, Oxford. Series I. Qualitative Exercises. Crown 8vo., cloth, \$3.

"An invaluable work for those who are beginning to learn practically the beautiful science of Chemistry."—MEDICAL PRESS AND CIRCULAR.

FORMS OF ANIMAL LIFE. Illustrated by Descriptions and Drawings of Dissections. By G. ROLLESTON, M.D., F.R.S., Linacre Professor of Physiology, Oxford. Demy 8vo., cloth, \$6.

"To students attending classes in our Universities and elsewhere, to those working in their own studies, to all interested in any branch of Comparative Anatomy, we most earnestly, and with the confidence which comes of experience, commend 'Forms of Animal Life' as a thorough piece of work, and certainly the best book on Comparative Anatomy in our language."—QUARTERLY JOURNAL OF MICROSCOPICAL SCIENCE.

BOOK-KEEPING. By R. G. C. HAMILTON, Accountant to the Board of Trade, and JOHN BALL (of the firm of Messrs. Quilter, Ball, and Co.), Examiners in Book-keeping for the Society of Arts' Examination. Third Edition. Extra fcap. 8vo., limp cloth, 60 Cents.

"How many a fine young, nay even old, fellow has been cast away and

wrecked by not knowing how to keep a cash account, or to make up a balance sheet. A prudent man ought to be 'au fait' at both, and Messrs. Hamilton and Ball show in the most provokingly easy manner how the tasks can be accomplished. The authors modestly say that their treatise is one of an elementary character, but to us they appear to have exhausted their subject."—ARMY AND NAVY GAZETTE.

IX.—MENTAL AND MORAL PHILOSOPHY.

THE ELEMENTS OF DEDUCTIVE LOGIC, designed mainly for the use of Junior Students in the Universities. By T. FOWLER, M.A., Fellow and Tutor of Lincoln College, Oxford. Fourth Edition, with a Collection of Examples. Extra fcap. 8vo., cloth, \$1.

"Mr. Fowler appears to us to have accomplished his task skilfully and usefully. His book contains all the essential details of its subject, is clearly expressed, and embodies the result of much accurate thought."—GUARDIAN.

THE ELEMENTS OF INDUCTIVE LOGIC, designed mainly for the use of Students in the Universities. By the same Author. Extra fcap. 8vo., cloth, \$1.50.

"A most useful handbook, mainly intended for University students, but which will be a convenient book, also, for those whose student days are over, but who wish to keep up with more recent methods."—LITERARY CHURCHMAN.

A MANUAL OF POLITICAL ECONOMY. By J. E. THOROLD ROGERS, M.A., formerly Professor of Political Economy, Oxford. Extra fcap. 8vo., cloth, \$1.25. Second Edition, with Index.

"Political economy is not a subject of which in these days sensible men can afford to be ignorant. Much of the ignorance which prevails respecting it will be cut at the root, if the able manual of Mr. Rogers is used extensively in our schools and colleges."—GUARDIAN.

X.—ART.

A HANDBOOK OF PICTORIAL ART. By the Rev. R. ST. J. TYRWHITT, M.A., formerly Student and Tutor of Christ Church, Oxford. With coloured Illustrations, Photographs, and a chapter on Perspective, by A. MACDONALD. 8vo., half morocco, \$8.

"Past experience of Mr. Tyrwhitt's powers as an observer and a writer had led us to anticipate a good book on the subject of art, and we have not been disappointed. His work is not only well and pleasantly written, but full of useful information and valuable suggestions."—CAMBRIDGE UNIVERSITY GAZETTE.

A TREATISE ON HARMONY. By the Rev. Sir F. A. GORE OUSELEY, Bart., Mus. Doc., Professor of Music in the University of Oxford. 4to., cloth, \$4.50.

"The whole of the subject is expounded with such perspicuity that it must be the fault of those who study it if they do not thoroughly master all that is set before them."—ST. JAMES'S CHRONICLE.

A TREATISE ON COUNTERPOINT, CANON, AND FUGUE, based upon that of Cherubini. By the Rev. Sir F. A. GORE OUSELEY, Bart., M.A., Mus. Doc., Professor of Music in the University of Oxford. 4to., \$6.

"We can approve the work as one likely to do excellent service at a time when the study of musical theory is fast spreading."—PALL MALL GAZETTE.

THE CULTIVATION OF THE SPEAKING VOICE. By JOHN HULLAH. Crown 8vo., cloth, \$1.25.

"The volume, if rightly employed, may be one of the most useful books in the excellent series to which it belongs."—GLASGOW DAILY HERALD.

XI.—LAW.

GAII INSTITUTIONUM JURIS CIVILIS COMMENTARIUM QUATUOR; or, Elements of Roman Law by Gaius. With a Translation and Commentary, by EDWARD POSTE, M.A., Barrister-at-Law, and Fellow of Oriel College, Oxford. 8vo., cloth, \$6.

"Our author has given us an admirable version, and though he often uses a paraphrase where the sentence could be literally translated, it is allowable, because the paraphrase is the truest rendition of the idea intended to be conveyed by the original. Mr. Poste's commentary shows that he has read much, and that he has digested what he has read. It is learned, searching, and suggestive."—SCHOOL BOARD CHRONICLE.

ELEMENTS OF LAW, CONSIDERED WITH REFERENCE TO PRINCIPLES OF GENERAL JURISPRUDENCE. By WM. MARKBY, M.A., Judge of the High Court of Judicature Calcutta. Crown 8vo., cloth, \$2.50.

"One of the best works that have appeared on the subject of General Jurisprudence since the publication of Mr. Austin's Lectures."—WESTMINSTER REVIEW.

OUTLINES OF TEXTUAL CRITICISM APPLIED TO THE NEW TESTAMENT. By C. E. HAMMOND, M.A., Fellow and Tutor of Exeter College, Oxford. Extra fcap. 8vo., cloth, \$1.50.

"One of the most practically useful handbooks we have ever seen. . . We wish that our Bishops were able to insist on all their candidates for Holy Orders being well up in such a handbook as this."—THE LITERARY CHURCHMAN.

THE MODERN GREEK LANGUAGE IN ITS RELATION TO ANCIENT GREEK. By E. M. GELDART, B.A., formerly Scholar of Balliol College, Oxford. Extra fcap. 8vo., cloth, \$1.25.

A SYSTEM OF PHYSICAL EDUCATION: THEORETICAL AND PRACTICAL. ' With 346 Illustrations drawn by A. Macdonald, of the Oxford School of Art. By ARCHIBALD MACLAREN, The Gymnasium, Oxford. Extra fcap. 8vo., cloth, \$2.25.

"The work before us is one which should be in the hands of every schoolmaster and schoolmistress. It is marked in every line by good sense, and is so clearly written that no one can mistake its rules."—
LANCET.

LEXICONS.

A GREEK-ENGLISH LEXICON. By HENRY GEORGE LIDDELL, D.D., and ROBERT SCOTT, D.D. Sixth Edition, Revised and Augmented. 1870. 4to., cloth, \$12.

A GREEK-ENGLISH LEXICON, abridged from the above, chiefly for the Use of Schools. Fourteenth Edition, carefully revised throughout. 1871. Square 12mo., cloth, \$3.

